APPLETONS'

# CYCLOPÆDIA OF APPLIED MECHANICS:

## A DICTIONARY

OF

Mechanical Engineering and the Mechanical Arts,

ILLUSTRATED WITH

NEARLY FIVE THOUSAND ENGRAVINGS.

EDITED BY

PARK BENJAMIN, PH. D., LL. B.

*IN TWO VOLUMES.*

VOL. I.

NEW YORK:
D. APPLETON AND COMPANY,
1880.

# PREFACE.

The present Cyclopædia is not a revision of the well-known "Dictionary of Mechanics," issued by its publishers more than a quarter of a century ago, but is an entirely new work. The amount of matter retained from the "Dictionary" bears but an insignificant proportion to the present contents. The plan of the work has been materially changed; not merely so as greatly to increase the number of subjects treated and to group them more logically, but to give a connected view of the chief types of each class of invention, to exhibit clearly their relations to each other and the principles of construction involved in them, and in most cases to present results of their actual working from well-authenticated records. Special efforts have also been directed toward rendering the information given of such practical utility that the work may serve as a trustworthy guide to the engineer and mechanical student in their every-day avocations. To this end, simplified rules have been introduced, with plain examples of their application; graphic methods have been preferred to those involving mechanical demonstration; and facts generally have been combined wherever possible in condensed tabular form. All the principal mechanical inventions and discoveries which have contributed toward the vast progress accomplished during late years in science and the arts—and more particularly those which have attracted the world's attention at the great International Expositions of Vienna in 1873, Philadelphia in 1876, and Paris in 1878—will be found described in these pages. Where the magnitude of a subject has precluded its treatment in detail, ample bibliographical references are supplied, which will direct the reader in the path of closer investigation.

The editor gratefully acknowledges his indebtedness to his contributors for the preparation of many important original articles, and for valued counsel. While care has been taken to accord proper recognition to all authorities quoted, special credit is due to the "American Cyclopædia" for illustrations and some few selections from the text of the mechanical and scientific articles.

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# CYCLOPÆDIA

OF

# APPLIED MECHANICS.

ABACUS. An instrument employed by the ancients for facilitating calculations; similar to that now frequently employed for teaching children the rudiments of arithmetic, and which is commonly sold in our stationers' shops. It usually consists of twelve parallel wires, fixed in a light rectangular frame; each wire carrying 12 beads or balls. There are thus 12 times 12, answering to the common multiplication-table, all the results of which it demonstrates to the dullest capacity. All the operations of addition or subtraction are likewise performed by it, by merely moving the beads from one side to the other of the frame. By thus smoothing the difficulties of acquiring arithmetical knowledge at the very outset, and rendering it quite obvious and amusing at the same time, the apparatus becomes one of considerable importance in education.

Another kind of abacus consists of a series of parallel wires fixed in a frame like the former. On each wire there are nine little balls; the lowest stand for *units*, the next above for *tens*, the next

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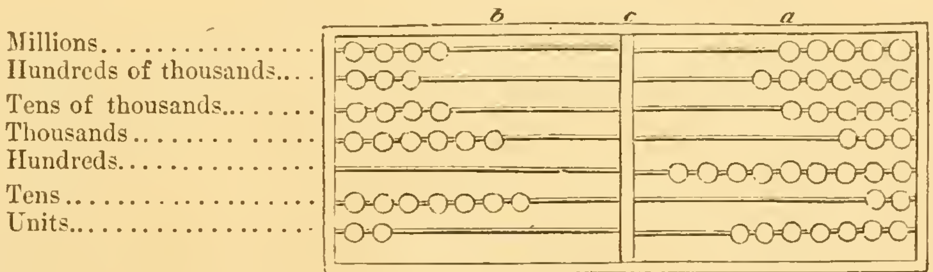


*hundreds*, and so on up to any number. The frame is divided into two compartments, *a* and *b*, by a cross-wire at *c*, which is sufficiently raised above the wires to allow the little balls to slide under it. Suppose the whole 63 balls to be placed in the compartment *a*, and it be proposed to note the sum of 4,346,072, it is effected by sliding the balls shown in *b* from their previous situation in *a*. See Calculating-Machines.

ACCUMULATOR. An apparatus used for working hydraulic cranes, lifts, and other machines where a steady, powerful pressure of water is required. Fig. 2 represents the portable accumulator used in connection with other hydraulic machinery at the St. Gothard Tunnel. It is interposed between the pump and the lift. It consists of a vertical cylinder, in which a piston travels, and which has to be loaded to a weight equivalent to 450 lbs. per square inch. When the lift is not in operation, the piston is raised to an extent proportionate to the quantity of water introduced, which it returns to the lift when the ingress-cock of the latter is opened. The diameter of the piston is 11.81 inches, and the stroke is 66.93 inches. The volume of water contained is 26.2 gallons, and the pressure on the piston should be 21.18 tons; the piston and cross-head weigh 1.18 ton. A load of 20 tons of lead-ingots is suspended to the cross-head at the top of the piston. These can be removed at will to facilitate the moving of the apparatus from place to place on the works.

The accumulator illustrated in Fig. 3 admits of the use of a long cylinder of small diameter. The

weight of masonry $M$, rests upon the cylinder $C$, and entirely surrounds the same. No guide is therefore needed to control the vertical movement of the weight, and the centre of gravity of the

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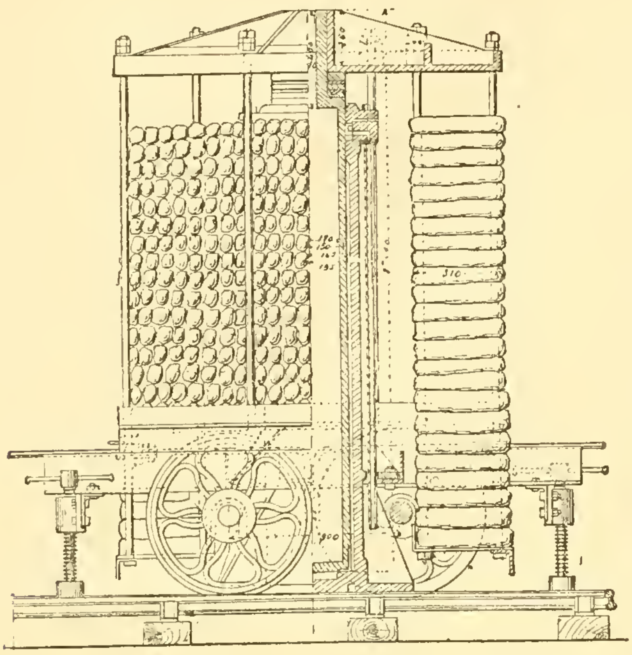

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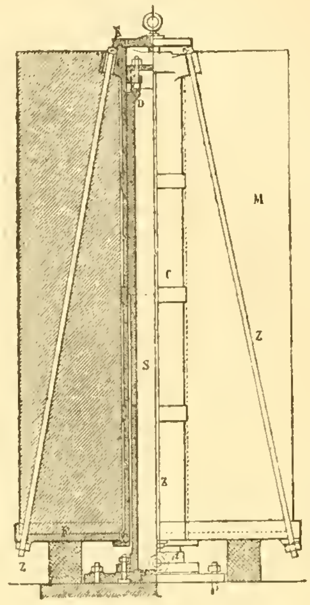

latter is situated low down. The plate $F$ is in two portions, consolidated by the screw-rods $Z$. The upper joint has a stuffing-box, to which access may be had through the cover $K$.

ADDRESSING-MACHINE. An apparatus used for affixing the addresses on a large number of missives, such as newspapers, upon which the same series of names must be inscribed as the day of issue recurs. There are two general forms of this machine. In one the addresses are separately printed on slips of gummed paper, which are fed from the apparatus, which cuts off each address in turn, and allows the latter to remain attached to the wrapper. The other mode is to set up the type of each address in a form, and so to arrange the forms that they are successively presented at a spot to which the enveloped papers are consecutively fed. A large number of these machines have been patented.

ADHESION is the molecular attraction exerted between bodies in contact. It occurs between solids and solids, liquids and solids, liquids and liquids, gases and solids, gases and gases, and gases and liquids. The adhesion between two plates of the same material is the same as that between one of the plates and any material which possesses a less adhesive property. Adhesion is supposed to manifest itself at an appreciable distance before actual contact of bodies. The ascent of liquids in capillary tubes is a result of adhesion, as well as the spreading out of liquids between two surfaces kept in close proximity. The chain-pump, in which the water is carried up by a simple chain in a tube, is a practical example of adhesion of liquids to solids. The adhesion of gases and solids is illustrated by the adhesion of air around a piece of solid iron, which causes it to float on melted iron. In the Giffard injecter a blast of steam is used to carry water by its adhesion to it into the boiler against its own pressure.

The adhesive force on railroads may be estimated approximately by multiplying the weight of the locomotive in tons which rests on the driving-wheels by a coefficient of adhesion for said wheels. This coefficient is with dry rails 670; very dry rails 560; under ordinary circumstances 450; wet rails 314; in snowy or frosty weather 225. On horse-railroads the coefficient varies from 300 to 400 in snow and frost.

ADIT. The horizontal opening by which a mine is entered, or by which water and ores are carried away. An adit is termed a cross-cut when run for purposes of exploration in a direction transverse to the general bearings of the veins or lodes. The great adit in Cornwall, Wales, drains the waters from the Gwennap and Redruth mines, and is nearly thirty miles in length.

AGRICULTURAL MACHINERY. Agricultural machines and implements are so multifarious that to facilitate their consideration a system of classification is necessary. Such a system may be based on the history of every crop; hence we have—

1. Implements for clearing ground, breaking it, and otherwise preparing it for the reception of the seed.
2. Implements for depositing the seed.
3. Implements for the cultivation of the plant.
4. Implements for gathering crops.
5. Implements for preparing the crops for market.
6. Miscellaneous implements applicable to various farm-uses.

These classes will be considered in their order, and examples of machinery given under each division. Dairy implements are principally referred to under DAIRY APPARATUS, CHURNS, and CHEESE-MAKING; farm-engines, under ENGINES, STEAM, FORMS OF. See also DRAINAGE, IRRIGATION, and MILLS.

1. *Implements for clearing, breaking Ground, etc.*

*Stump-Pullers.*—The primitive method of extracting stumps is to hitch on a yoke of oxen, and, after cutting away the earth from around the stump as much as possible, drag the latter from the soil by main strength. Explosives are frequently employed to blow the stump to pieces. A mechanical apparatus for stump-extraction is represented in Fig. 4. It consists of two beams placed at right angles, and carrying each a wheel at their outer ends. The journal of the larger wheel on the right is hinged to its beam so that the wheel may be turned back parallel to the beam for convenience in drawing the machine from place to place. A loop secured to the ends of the hinged journal carries a hook, to which the harness of the horse is hitched. Near the intersection of the beams is placed a guide for a knife, which may be adjusted by a lever as deep in the ground as is desired. To the rear of the beam on the left is attached a loop that encircles the stump. The horse is hitched to the apparatus as shown.

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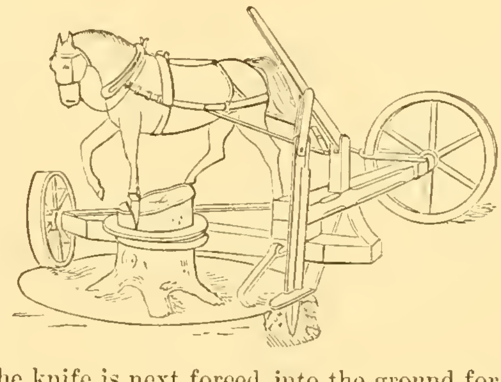

In operating the machine the loop is first dropped in place, and a ring is placed above it. A wedge is then driven into the top of the stump so as to fasten the ring, the latter serving both to prevent the loop from slipping off, and also as a band to keep the wedge from spreading the lower part of the stump so as to tighten the loop. The knife is next forced into the ground for five or six inches, so that, on driving the horse around the stump, it cuts off such side roots as may lie in its path. At each round the knife is driven in deeper until all the roots are divided. The hook shown is then dropped and held down by the foot until it catches upon a root. A few rounds twist off this last, and the stump may then be easily raised from the ground.

*Ploughs.*—The plough is primarily designed to prepare the ground for cultivation by turning it over, thus burying the weeds and loosening the earth. Modifications of the plough, however, have of late been contrived to assist in cultivating operations, such as the destruction of weeds, loosening the surface of the earth, or casting the same against the rows of the grain or plant, as the case may be, and ploughs of this description will be treated of under the head of *Cultivators*, by which term they are now generally known. The modern plough consists of a frame, to which horses may be attached, and to which is fastened a device to detach (in advance of the share) the furrow from the unploughed land; a share to sever the bottom of the furrow from the land beneath, a gauge-wheel to regulate the depth to which the share shall enter the soil, and a mould-board to invert the furrow.

In Fig. 5 is represented an improved form of plough, made by the Ames Plough Co. *A* is the frame; *B B* are the handles by which the operator guides the plough; *C* is the gauge-wheel, which runs upon the surface of the soil and determines by the distance between its perimeter at the bottom and the bottom of the ploughshare the depth of the furrow; *D* is the coulter which severs the furrow-slice from the land in advance of the share; *E* is the mould-board, and *F* is the clevis to which the draught is applied.

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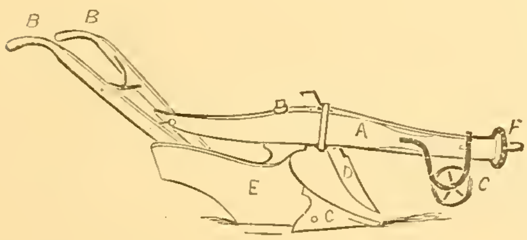


The manner in which the furrow is turned by the plough is of considerable importance. Greensward land may be ploughed with the furrows turned completely over so as to kill the herbage, as shown in Fig. 6; or it may be lap-furrowed, as shown in Fig. 7. The difference is, that in the former case the ploughed land lies solid, and is difficult to break up, whereas in the latter the land will break somewhat of itself, while there will remain at the same time beneath

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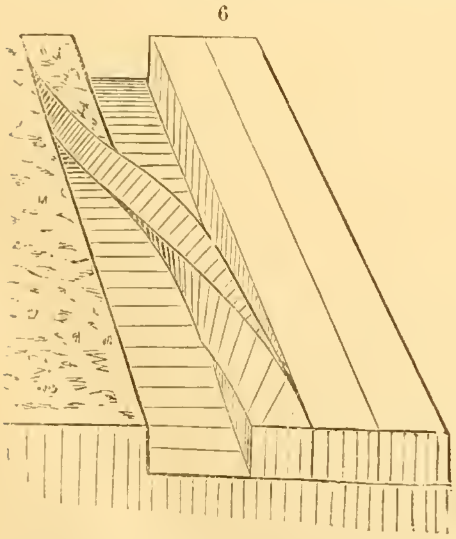

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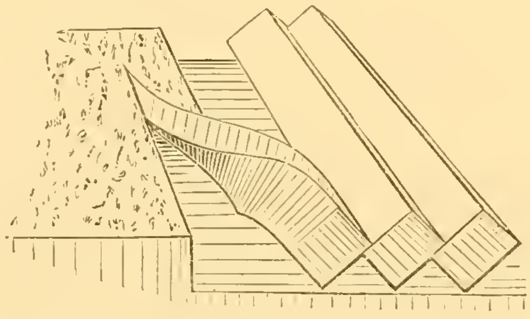

the furrows the hollow triangular spaces shown in Fig. 7. Hence, when the cultivator, or clod-crusher, is passed over the land, the soil will be more thoroughly broken up. In arable land—that is, land that has been well ploughed before, and is not of a very clayey nature—the furrows may be

turned completely over with such a short turn that the twisting of the soil itself will cause it to break up, as shown in Fig. 8. Still another kind of ploughing is performed by the double Michigan plough, the furrows of which are shown in Fig. 9. The upper furrow merely skims or pares off the upper

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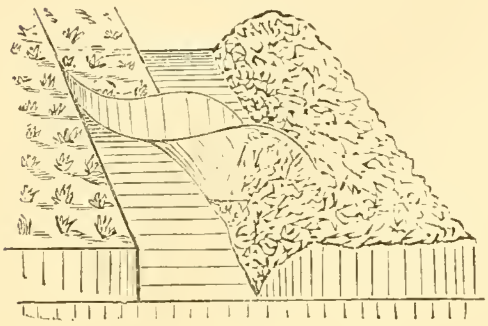

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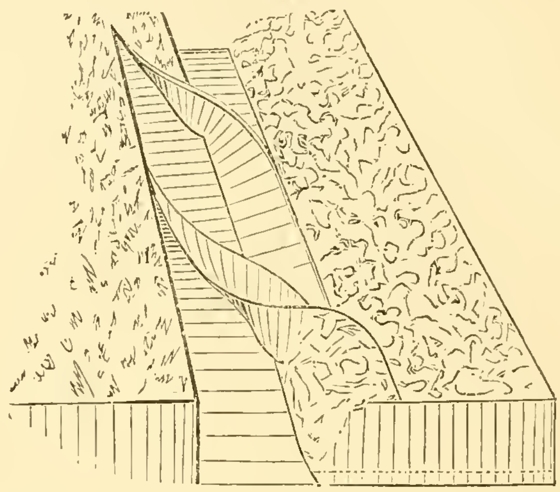

portion of the sod and inverts it in the bottom of the furrow—a trench left by the bottom plough in its previous traverse. By this method the soil is well broken up. The ploughing may be deep, and the roots of grass, weeds, etc., are thoroughly buried.

The amount of twist given to the furrow is determined by the form of the mould-board. All other things being equal, a long twist will require the least power to draw, while a short one will more thoroughly break up the soil. The manner in which the furrows will lie depends upon the angle at which the cutter or coulter is set. Thus in Fig. 10 the cutter, being set at an angle as shown, is

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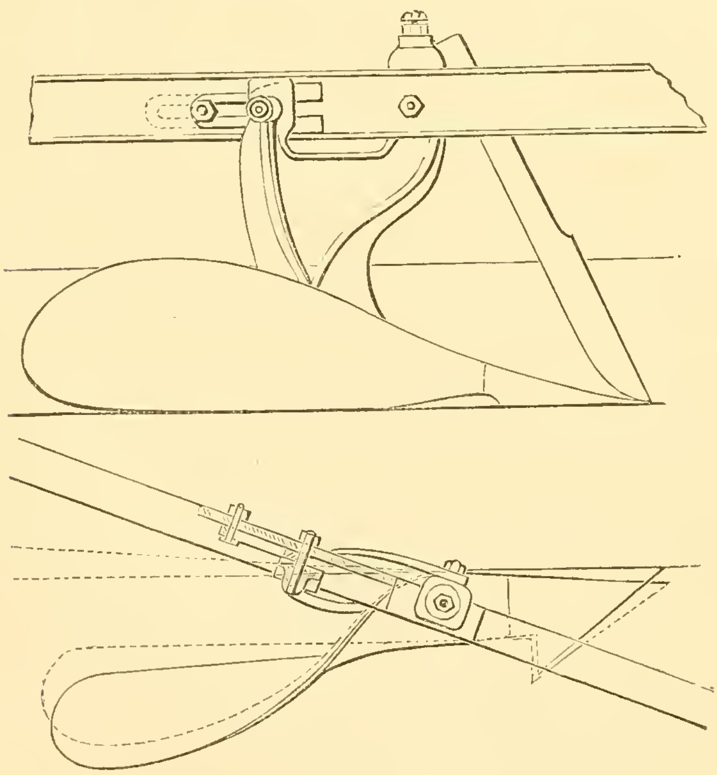

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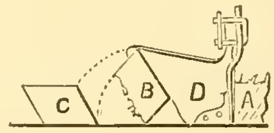


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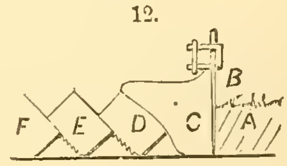


proper for ploughing flat furrow-slices, and stands as much inclined toward the mould-board side as the land-side (as the side of the plough next to the unploughed land is termed) does, and it is generally considered best to incline it even a little more, in order to obtain that beveled edge of the furrow-slices so essential to their sure and finished matching, side by side, as they come from the plough, and to do *perfectly flat* work.

In Fig. 11 *B* and *C* are the furrows, and the dotted lines denote the direction in which the furrow *B* will fall, *D* being the mould. In order to plough lap-furrowed slices, the cutter or coulter is adjusted as shown in Fig. 12, in which *A* represents the land-side, or unploughed land, *B* the coulter or cutter, *C* the mould, and *D*, *E*, and *F* the furrows already turned. The forward inclination of the coulter or cutter may be made greater or less, but it is always set with the point in advance. In some cases a circular cutter takes the place of the knife-coulter, because it will sever fibrous roots the more readily. The width of the furrow depends upon the position of the plough with reference

to the line of draught of the horses, and is usually adjusted through the medium of either the draught-rod or of the clevis, and examples of each of these methods will be found in our illustrations. To illustrate the influence of the line of draught upon the plough, however, let *b* in Fig. 13 represent the

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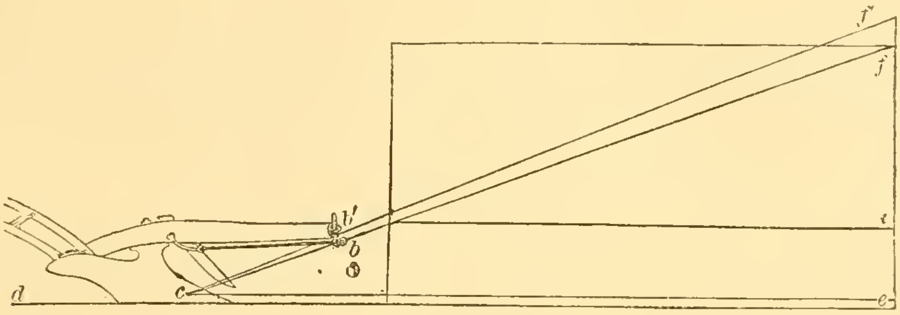


forward end of the plough-beam, and *c* the centre of resistance on the plough, which may be assumed at two inches above the plane of the base of the plough, *d c*, though it is liable to constant changes, from the depth of the furrows and constant inequalities in the soil.

We have first to consider the particular form of those parts through which the motive power is brought to bear upon the plough. It is evident that the motive force acts in a direct line from the hook or ring at the shoulder of the animal, to the centre of resistance, and a straight bar or beam, lying in the direction *c b*, and attached firmly to the body at *c*, would answer all the purposes of draught, perhaps better than the present beam, but for considerations of convenience. The draught, however, not being the end in view, but merely the means by which the end is accomplished, the former is made to subserve the latter; and, as the beam, if placed in the direct line *c* to *b*, would obstruct the proper working of the plough, we are compelled to resort to an indirect action to obtain the desired effect. This indirect action is accomplished by means of an angular framework, consisting of the beam, and the body of the plough, so strongly connected together as to form an unyielding structure. The effect of the motive force applied to the framework at the point *b*, and in the line *b* to *f*, produces the same results as if *c b* were firmly connected by a bar in the position of the line *c* to *b*, or as if that bar alone were employed.

The average length of the trace-chains being ten feet, including all that intervenes between the clevis of the plough at *b*, and the horse's shoulders, let that distance be set off in the direction *b* to *f*; and the average height at the horse's shoulders, where the chains are attached, being four feet and two inches, let the point *f* be fixed at that height above the base-line *d e*. Draw the line from *f* to *c*, which is the direction of the line of draught acting upon the assumed centre of resistance *c*; and if the plough is in proper trim it will coincide also with the ring of the clevis, *e c f* being the angle of draught and equal to 20°. It will be readily perceived that, with the same length of hames, the angle *e c f* is invariable; and if the plough has a tendency to rise at the heel, or run on the point under this arrangement, it indicates that the ring at *b* is too *high* in the clevis. Shifting the ring one or more holes downward will bring the plough to work evenly upon the base of the land-side, or work flat.

If the plough has a tendency to rise at the point of the share, the ring *b* is too *low*, and must be moved by raising it one or more holes in the clevis. If a pair of taller horses be harnessed to the plough, the draught-chains, depth of furrow, and soil remaining the same, we should have the point *f* raised, suppose to *f'*; by drawing the line *f'* to *c*, we have *e c f'* as the angle of draught, which will be 22°, and the *ring* will be found to be *below* the line of draught *f' c*; and if the draught-chains were applied at *b*, in the direction *f' b*, the plough would have a tendency to rise at the point of the share, by the action of that law of forces which obliges the line of draught to coincide with the line which passes through or to the centre of resistance; hence the ring would be found to rise from *b* to *b'*, which would raise the point of the share out of its proper direction. To rectify this, the ring must be raised in the clevis by a space equaling that between *b* and *b'*, causing it to coincide with the true line of draught, which would again bring the plough to work evenly on the base of the land-side and run flat.

The foregoing principles are substantially such as are adopted by the most experienced ploughmen, and, if properly applied, will not only do the best work, but accomplish it with the greatest ease to themselves and their team. If the power (or team) is not rightly applied, good work cannot easily be done; for if the plough inclines in or out of the ground too much, or takes too wide or too narrow a furrow-slice, the ploughman must exert force to direct it properly, in addition to that required to overcome the obstacles and inequalities in the soil; but if the power be rightly applied, the plough will move so accurately as not only to perform good work with more ease to both ploughman and team, but, in soils free from obstructions, even without a guide.

To effect a proper horizontal movement, the clevis at *b* or draught-rod (if one is used instead of a clevis) must be adjusted and confined at that point, moving it to the right or left, if necessary. This will cause the plough to take the proper width of furrow-slice, which, in sod, should be wider or narrower according to the depth of furrow, or, rather, the thickness of the furrow-slice required; for as the thickness is increased, so also must be the width in proportion, in order to turn it easily and perfectly over, particularly when the furrow-slices are required to be laid over level, and side by side. The proportion in ordinary sod should be seven by ten, or the width or depth should be varied *only in this proportion.*

In determining the width of furrow-slice, some regard must be had to the strength of the particular sod to be turned; for the plough will turn over a wider slice in a strong, stiff sod than when running in one more easily broken, or it will cripple and double when raised to a perpendicular position, thus only doing the work called "cut and cover."

When the slices are required to be laid at an angle and lapped each one upon the preceding, the proportion of width should be as seven to ten, thus setting the furrows at an angle of 45°, which is the position of furrow presenting the greatest attainable surface to the action of the atmosphere, and the greatest cubical contents of soil to the action of the harrow in preparing a seed-bed.

In Fig. 14 is shown a prairie-breaking plough. The furrows in this class of ploughing are usually about 4 inches deep, and from the fibrous roots in and compact nature of the soil the duty is very heavy; hence the length of the plough is increased, and a wheel-coulter is employed. The line of

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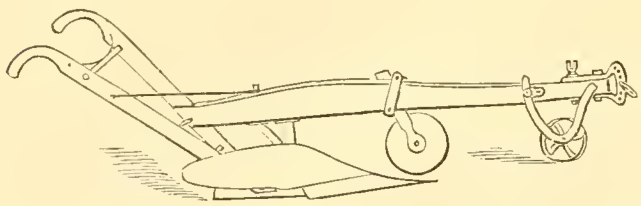

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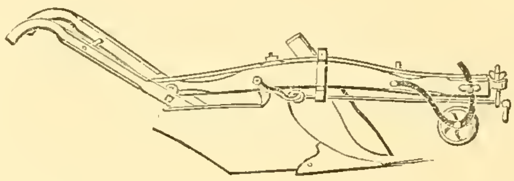

draught is regulated by the clevis being moved laterally to the width of the furrow, and vertically to steady the plough as regards depth.

The double Michigan or "sod and subsoil" plough, Fig. 18, has some important advantages. The forward or skim plough pares off a sod a few inches in thickness, and inverts it into the bottom of the previous furrow. The second or main plough follows, and throws up the lower soil, completely burying the inverted sod, and giving a loose, mellow surface to the field. This forms an excellent preparation for all crops, particularly carrots and other roots, which grow best in a deep, loose bed of earth; and, where a portion of the subsoil improves the top-soil by being mixed with it, a permanent advantage results. A greater depth may be attained by the use of this double plough than

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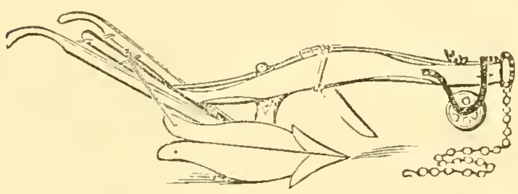

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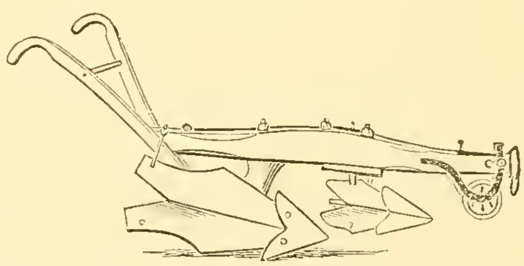

with one having a single mould-board, in sod-ground, because the inversion will be complete even if the width of the furrow is only one-half the depth. But, with a single plough, the width must be considerably greater than the depth, or the sod will be thrown on its side or edge, and cannot be inverted. There is one disadvantage, however, in the use of the double plough. A greater force is required to make two cuts in the soil, one above the other, than one cut with a single share. For this reason more force must be used to plough a field to a given depth, say one foot, with the double

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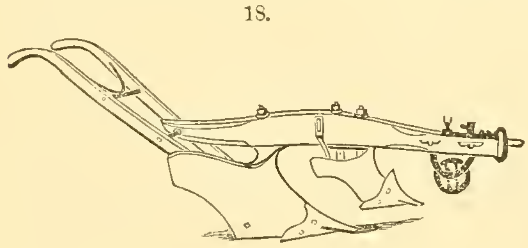

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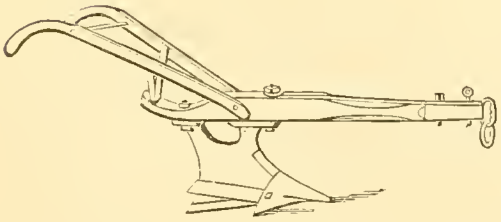

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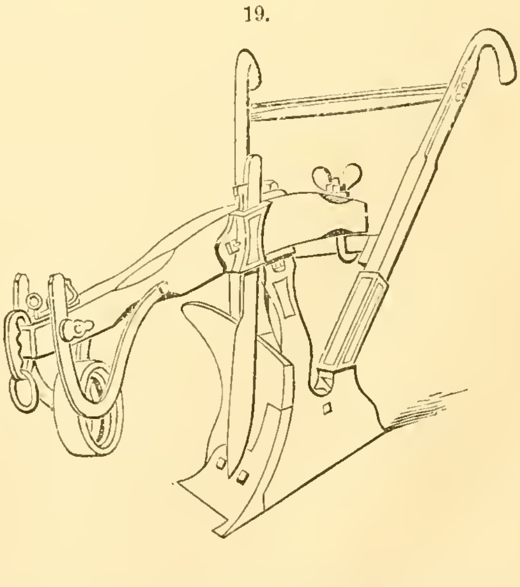


than with the single plough. But the single plough, in order to reach this depth, would require to be so large, and to turn so wide a furrow, that no ordinary amount of team could be had to do the

work. And, in addition to this difficulty, the inverted surface would not be so well pulverized as by the use of the double plough.

Side-hill or swivel ploughs are designed to throw the furrow-slice down-hill, whichever way the plough may be moving. The plough is pivoted so that it may be moved from side to side of the beam when at the end of the furrow. The ploughing may then be done across and across the field instead of around it or in sections. Fig. 16 is an Ames side-hill plough. Another variety of the swivel or "turn-wrist" plough is shown in Fig. 17. It is so constructed that two ploughs attached to one beam are readily changed from one side to the other, turning the furrow-slices either to the right or left as desired. The forward plough turns the sod to the depth of about three inches, depositing it at the bottom of the channel; and the rear plough works to the depth of five to seven inches, raising and pulverizing the under or subsoil, and depositing it upon the forward furrow-slice, burying the sod below the reach of the harrow or cultivator.

Fig. 15 is a plough designed for deep tilling, and it may be taken as a representative of the class of ploughs used in sugar-cultivation. The line of draught is adjustable by the clevis, as shown. In the New York plough, Fig. 19, the line of draught for regulating the width of the furrow is adjusted at the end of the beam where it connects with the handle-frame. The handles may be kept nearly equidistant laterally from the share, giving a central draught.

21.

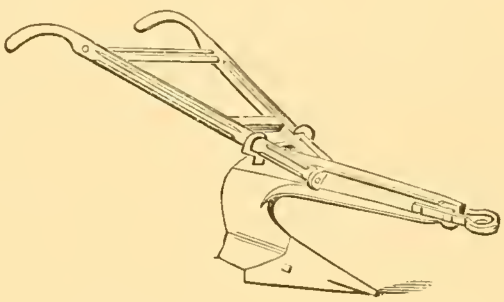


Fig. 20 is a Scotch subsoil plough, which is used for following directly after the turning-plough, and in the same furrow, breaking up, lifting a few inches, and pulverizing the subsoil. For making roads, the class of plough shown in Fig. 21 is used. Strength and durability are here prime requisites, as the principal duty is simply to loosen the ground, cutting a width of from seven to nine inches at a traverse.

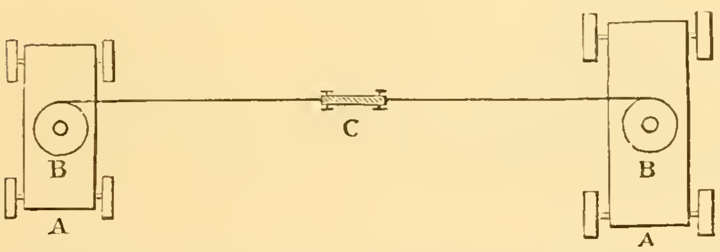
As regards the tractile power required to draw a plough, from experiments in England it appears that about 35 per cent. of the whole required draught is expended in overcoming the friction of the implement on its bottom and sides, about 55 for cutting the furrow-slice, and only about 10 per cent. for turning the sod. Hence the exclusive attention formerly given to forming the mould-board, as a means of reducing the draught, should have been directed more to lessening the force required for cutting the hard soil.

These data are not wholly satisfactory for the light ploughs of the United States.

To ascertain the amount of friction, suppose the plough weighs 100 lbs. Half its weight would be 50 lbs., the friction on the sole of the plough. The friction of the sides would vary greatly with ploughs, being very small with those having a perfect centre-draught, or with no tendency to press against the land on the left. The whole friction and force for lifting the sod would therefore be about 150 lbs.; leaving 250 lbs. as the force for cutting the slice. A very easy-running plough would leave a much smaller force—some as low as 200 lbs.

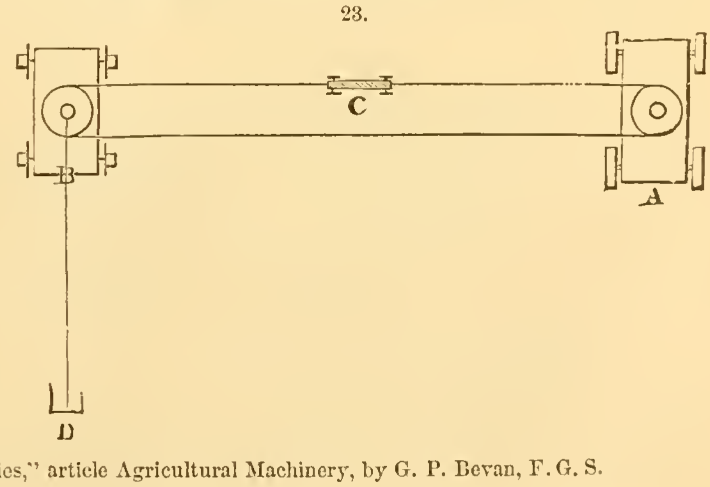
This estimate is liable to great variation. A wet and clayey soil would double the friction; a very hard piece of ground would add much to the force required for cutting the slice; if loose, the force would be comparatively small; or if quite moist, this force would be also much diminished; while the great difference in the draught of ploughs would vary the results still further. The estimate, however, for soil dry enough to be friable, and of medium tenacity, is probably not far from correct, for ploughing in this country—showing that most of the force required is for the act of cutting, and indicating the importance of giving special attention to the cutting edge.

22.




*Steam-Ploughing.*—This answers the use of a gang-plough hauled across and across or else around the field by means of wire ropes, the steam-engine remaining stationary. In Fig. 22 is represented Fowler's double-engine system,* which requires two engines, one on each headland, each of which alternately draws the cultivating implement across the field. Each engine is provided with a winding or hauling drum, which in turn pulls the implement and pays out the slack rope. This system is both simple and effective. The implement is drawn with considerable velocity—often much faster than a man can walk—and the steam drag or harrow will pass over from fifty to sixty acres of land per day. Fow-

23.

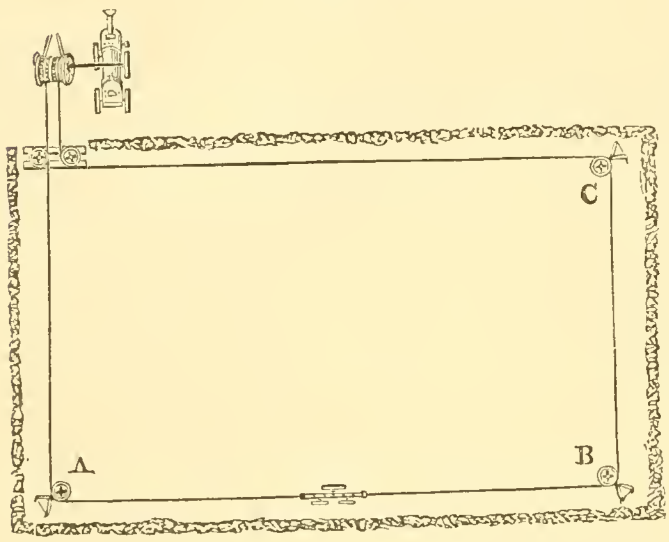



* From "British Manufacturing Industries," article Agricultural Machinery, by G. P. Bevan, F. G. S.

ler's double-engine system appeals to large capitalists, but the same firm also provides good single-engine sets for the use of smaller employers. The single-engine system (Fig. 23) requires an engine on one headland and a self-moving windlass on the other. The engine is provided with the patent Burton clip-drum, capable of hauling the cultivating implement backward and forward between the engine and windlass. Both engine and windlass travel along the two headlands opposite each other. A third system is offered in Fig. 24, in which the engine remains stationary, and the rope is arranged in an irregular triangle or square, while the implement passes to and fro between two fixed anchors, rendered movable at pleasure. This is called the "round-about system," because the rope is carried around anchors and incloses the space to be cultivated. The several systems thus slightly described will be more easily understood by reference to the accompanying diagrams. One of the main advantages of the "round-about" plan is that it enables the farmer to employ any ordinary traction-engine for ploughing purposes, and thus reduces the amount of capital required in commencing steam-cultivation.

The following particulars, taken from one of the Royal Agricultural Society's Implement Catalogues, will give the reader a good idea of what is included in a set of steam-cultivating implements. Messrs. J. Fowler and Co.'s double engine, 20 horse-power set, consists of a pair of 20 horse-power self-moving engines with single cylinders, fitted with single winding drums, 800 yards of best steel-wire rope, and works a thirteen-tined cultivator. There may be a six-furrow balance combined plough and digger in addition.

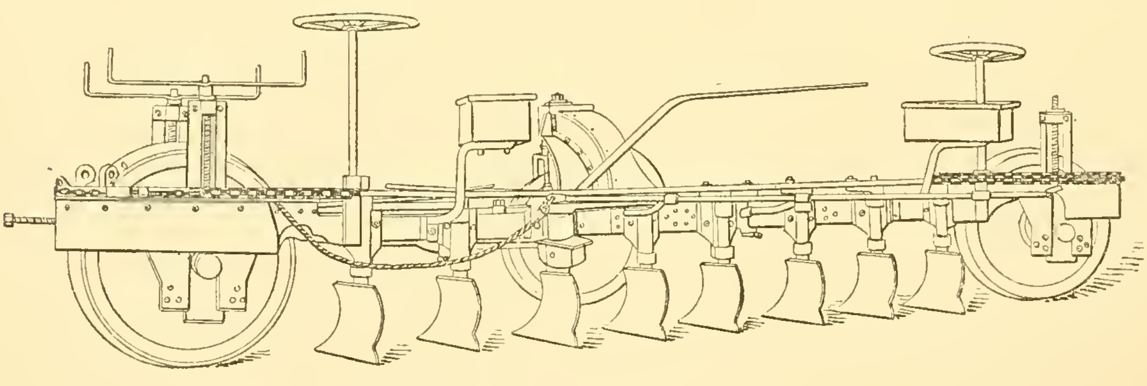
24.



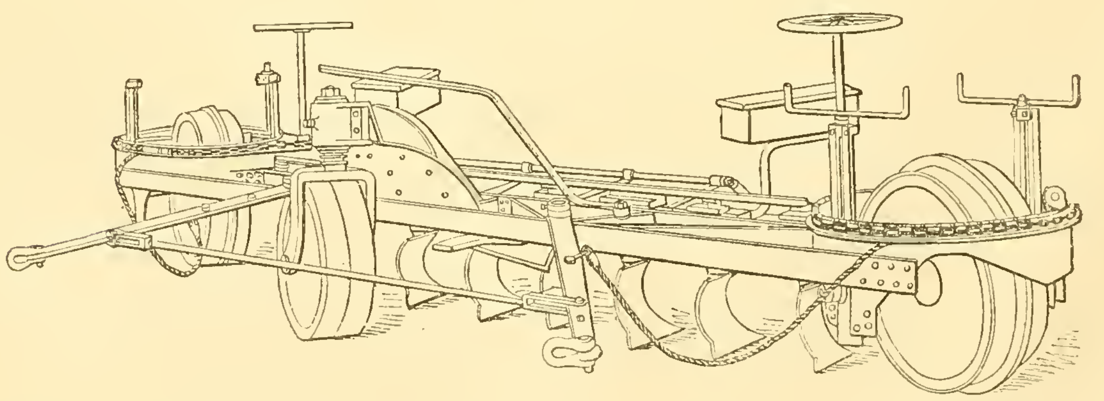

It appears from a test of Messrs. Fowler and Co.'s apparatus, made by the Royal Agricultural Society, that the machine was able to turn over soil in an efficient manner at a saving as compared with horse-labor on light land of $2\frac{1}{2}$ to 25 per cent.; on heavy land 25 to 30 per cent.; and in trenching 80 to 85 per cent.

*Gang-Ploughs.*—The gang-plough has a framework to which are attached two or more ploughs, together with a seat for the driver. Mechanical means are provided whereby the ploughs may be lifted entirely clear of or be adjusted to any required depth in the ground. The smaller and lighter gang-ploughs may be drawn

25.



26.



by horses after the manner of sulky-ploughs; but in many cases, and especially in England, gang-ploughs are employed for steam-ploughing, as previously described.

In Figs. 25 and 26 are given two views of an improved English gang cultivator-plough.

The frame, to which the ploughs are attached, stands on three wheels, of which the middle one is a caster-wheel, while the two end-wheels revolve in turn-tables, which lift or lower the main frame exactly by the depth of the furrow, according to the direction which is given to the wheel. The plough-skifes turn in sockets, and are connected by a long rod, working short levers, so that the turning round of one plough causes all the others to turn as well. There are, further, two connected horizontal pulling levers, by turning which either backward or forward the ploughs are also turned completely round, and locked. The ploughs themselves are shaped so as to cut with either end. While at work the main frame travels in a slanting position over the land, the front-wheel running in the preceding furrow, the hind-wheel on the unploughed ground, the ploughman steering the furrow-wheel.

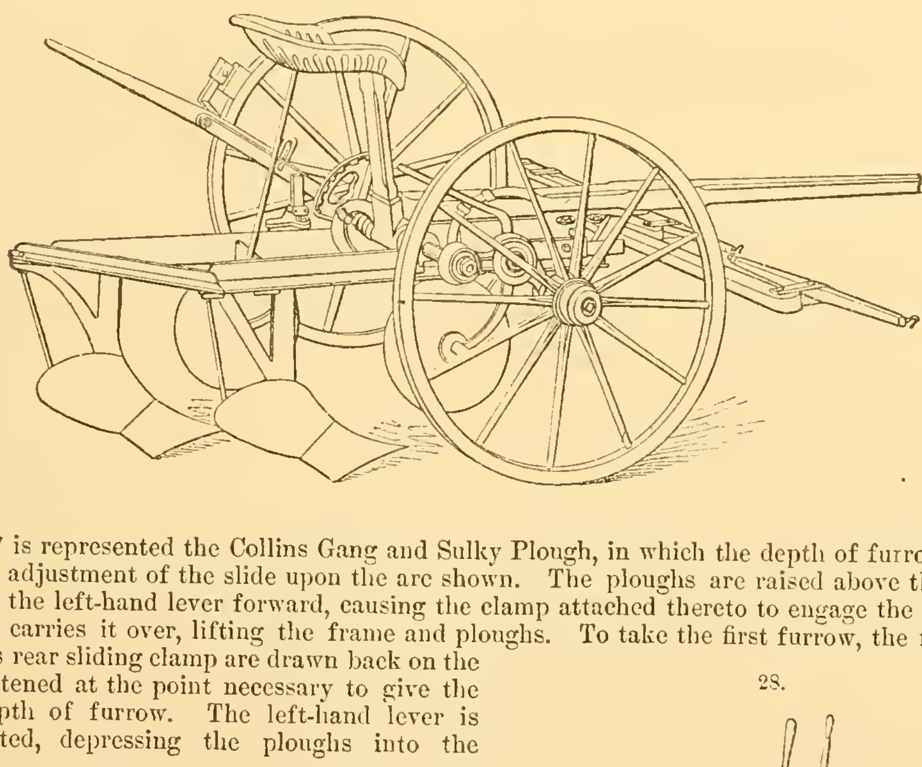
*Table showing Dynamometric Tests of Gang-Ploughs at Paris Exposition*, 1878. (1)

| NAMES OF CONTESTANTS. | Trials. | Surface Measure by Planimeter. | Length of trace. (2) | Mean ordinate. (3) | Corresponding effort. | Mean depth of furrow. | Mean width of furrow slice of the gang-plough. | Section of land turned. | Power necessary to displace 35.3 cubic feet of earth. Mean of two trials. | Length of furrow. | Time of travel. | Weight of Plough. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Square inches. | Feet. | Inches. | Foot-pounds. | Inches. | Inches. | Square feet. | Foot-pounds. | Feet. | Min. Sec. | Pounds. |
| Meixmoron de Dombasle, Nancy, France | Going. | 178.5 | 7.97 | 1.92 | 3595.5 | 5.9 | 26.4 | 1.098 | ........ | 524 | 4 8 | 543.4 |
| | Returning. | 174.7 | 7.75 | 1.85 | 3616.8 | 6.2 | 24.4 | 1.080 | 35421.2 | 524 | 4 42 | ...... |
| Deere & Co., Moline, Ill | Going. | 187.3 | 8.24 | 1.87 | 3651.9 | 6.3 | 27.1 | 1.213 | ........ | 524 | 4 12 | 572. |
| | Returning. | 195.2 | 7.79 | 2.06 | 4028.8 | 6.5 | 27.6 | 1.269 | 32881.7 | 524 | 4 22 | ...... |

(1) The ground was slightly inclined. (2) The base line on the paper ribbon of the dynamometer. (3) Mean distance between the base and profile lines on paper ribbon.

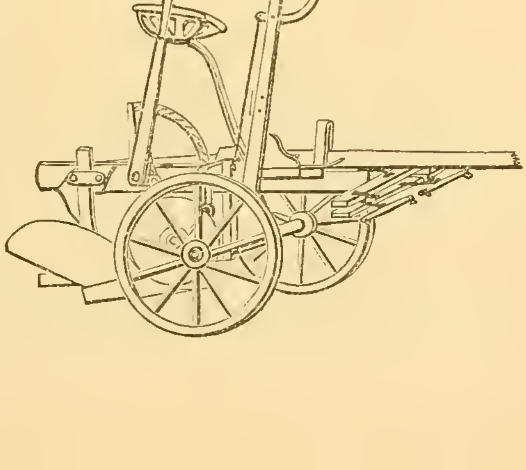
See *Scientific American*, xxxix., 162.

27.



In Fig. 27 is represented the Collins Gang and Sulky Plough, in which the depth of furrow is regulated by the adjustment of the slide upon the arc shown. The ploughs are raised above the ground by throwing the left-hand lever forward, causing the clamp attached thereto to engage the rim of the wheel which carries it over, lifting the frame and ploughs. To take the first furrow, the right-hand lever and its rear sliding clamp are drawn back on the arc and fastened at the point necessary to give the required depth of furrow. The left-hand lever is then retracted, depressing the ploughs into the ground.

28.

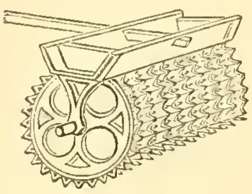


*Sulky-Plough.*—This name is given to single ploughs, which are mounted upon a frame on which a seat for the ploughman is arranged. The sulky-plough shown in Fig. 28 is arranged for three draught-horses. By applying the brake to the wheel the horses raise the plough out of the ground instead of the driver having to pull it out by main force. The team is hitched to the end of the beam instead of to the tongue or carriage, thus avoiding side-draught and relieving the weight from the horses' necks. Owing to the peculiar construction of the axle, the lowering of the plough into the ground throws the furrow-wheel down and the land-wheel up, keeping the plough

level, thereby avoiding all the trouble of leveling up with levers or screws. The depth of furrow can be instantly changed by the driver without getting off or stopping the horses. It can also be readily adjusted to take more or less land.

*Clod-Crusher.*—This machine is used to break up the land which is of such a stiff nature as to remain in lumps or clods after ploughing. In the implement illustrated in Fig. 29, it consists of about two dozen circular cast-iron disks, placed loosely upon an axle, so as to revolve separately. Their outer circumference is formed into teeth, which crush and disintegrate the clods as they roll over the surface of the field. Every alternate disk has a larger hole for the axle, which causes it to rise and fall while turning over, and thus prevent the disks from clogging.

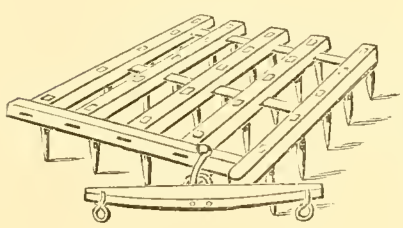
29.



This clod-crusher can be used only where the ground and the clods have become quite dry. Even then it packs the soil, and if followed by a harrow, with scarifier teeth, to loosen it again, it would prove an advantage. It is only in certain seasons that it is most successfully employed, or when quite dry weather follows a wet spring. As thorough tile-draining is generally adopted, it becomes less necessary.

*Harrows* are used to disintegrate and pulverize the ground after ploughing. Several forms of these implements are presented herewith.

30.



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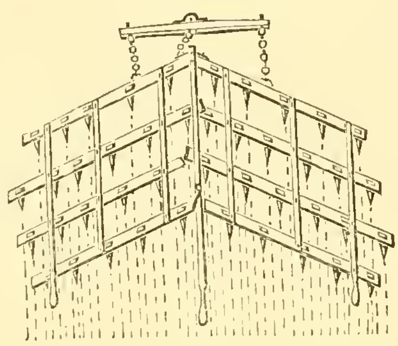

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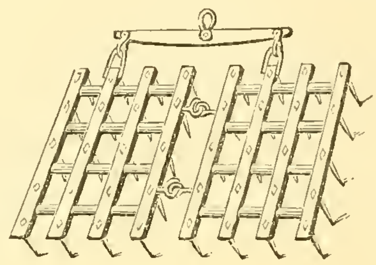
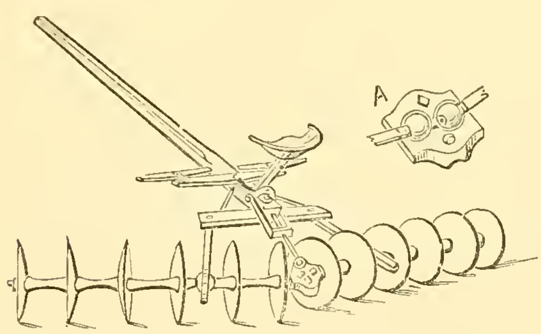


Fig. 30 is the ordinary square harrow; Fig. 31, the Friedmann harrow; and Fig. 32, the Scotch harrow. For land containing many fibrous roots, or much stiff clay, the disk or wheel harrow rep-

33.



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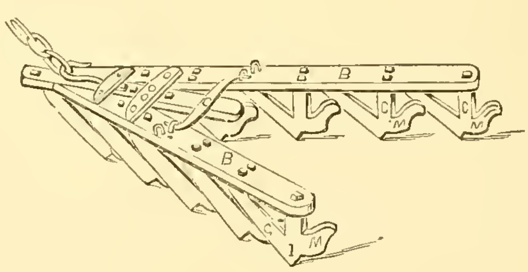
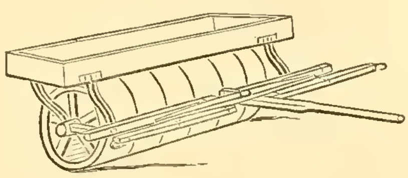


resented in Fig. 33 is used. . The wheel-gangs (that is to say, the shafts to which each row of disks is fixed) are attached to the pole and draught-bars by the ball-joint shown at *A*, so that each gang is free to conform by its own weight to the shape of the ploughed land-surface. The operation of this harrow is that of cutting and separating rather than of scratching, as in the case of spike-harrows. The shares harrow (Fig. 34) is especially adapted for pulverizing the freshly-inverted surface of sward-land, to a depth two or three times as great as the common harrow can effect. The teeth, being sharp, flat blades, cut with great efficiency; and as they slope like a sled-runner, they pass over the sod, and instead of tearing it up like the common harrow or gang-plough, they tend to keep it down, and in its place, while the upper surface of the sod is sliced up and torn into a fine, mellow soil.

35.



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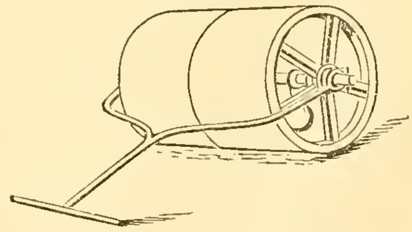


*Rollers* crush all sods and lumps that remain on the top of the ground after the harrow has passed, and force down small stones level with the surface. They render the field smooth for the cradle,

scythe, and rake, press the earth close about the seed, and secure a more sure and quick germination. On light and sandy lands they are invaluable, and in all cases their use has greatly increased the product. Much benefit is undoubtedly found in compressing the surface of such light soils, by preventing the escape of those gases from the manure so essential to vegetation, and which are so rapidly extracted by the sun and winds. Great advantage is gained by rolling early in the spring while the ground is yet soft. Clay lands, by heaving, pull to pieces and displace the roots of grain and grasses sown the previous autumn, and the heavy roller presses the roots and earth together to their proper position, when vegetation goes on again, and thus, in a measure, prevents what is termed winter-killing. Fig. 35 represents an approved form constructed wholly of iron, except the tongue and box, which are of wood. These rollers are made of various diameters, from twenty to thirty-six inches, in separate sections, each one foot long, placed on a wrought-iron shaft independently of each other.

Fig. 36 is a hand-roller used upon lawns and gardens. Additional weight is supplied by iron weights pivoted as shown to the axle.

2. *Implements for depositing Seed, etc.*

*Seed-Sowing Machines—Drills.*—These machines are mainly distinguished by the mechanical devices by which the drills are opened, seed fed, and drills reclosed upon the seed. Of these the feeding-device is the essential feature, and this usually involves either means for varying the quantity of seed fed by varying the escape-openings, or by positive mechanical movements variable in speed. The principal requirements are capability of distributing seed with a continuous and regular discharge from each distributor or grain-tube; accuracy in quantity of seed discharged; efficiency in regulating the same under all circumstances on inclined, level, or irregular land; changeability of the feed-apparatus to suit coarse or fine seed, and facility of adjustment.

Fig. 37 represents a sowing-machine to which a horse may be attached, or it may be pushed by hand. *A* is the seed-box, in the bottom of which is the seed-delivering device, which consists either of a brush *D*, or a revolving cylinder *C*. The former is employed for small, the latter for large seed. To change the quantity of seed sown, the speed of either of these feed-devices is increased as follows: *B* is a casting containing several diameters of gears upon one casting, which is either fast to the wheel or the axle. Into one of these gears is meshed a pinion fast upon an horizontal shaft or spindle, which by means of bevel-gears at the other end rotates the brush or cylinder as the case may be. Hence by changing the pinion at *B* from meshing into the larger or smaller gear at *B*, the rotations of the brush or cylinder may be increased or diminished, and the quantity of seed sown varied in consequence. The grain-spout enters the ground at its point, and therefore opens the drill ready to receive the seed, while the swing-board beneath the handles closes the earth over the sown seed, and the roller following compacts and levels the same over the seed.

37.

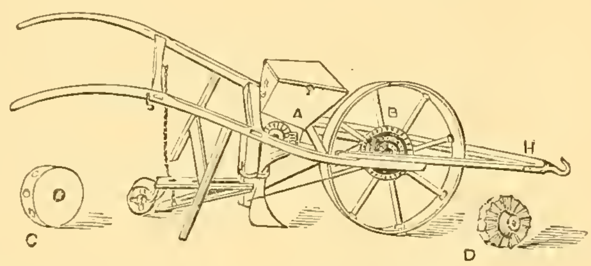
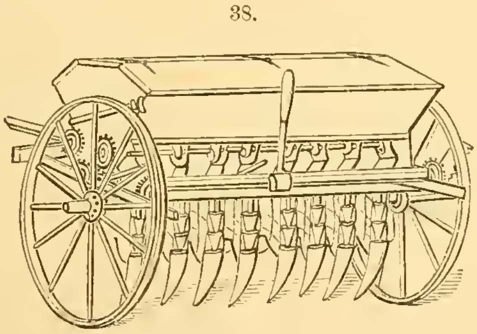



Fig. 38 is a Bickford and Huffman grain-drill. It contains eight dropping-tubes. The mode by which the grain is discharged from the hopper down these tubes is exhibited in section in Fig. 39,

38.



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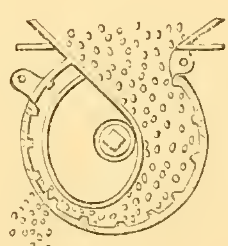

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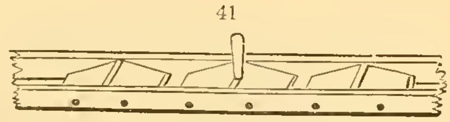
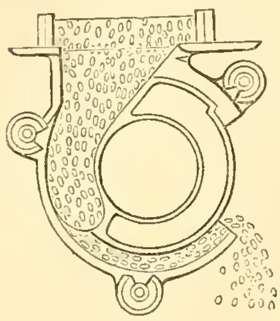


which shows the interior of the hopper, and a revolving wheel, the projecting rims of which form the bottom of the seed-holder; the axle causes this wheel to revolve, and the small projections on the interior of the rim carry the seed to where it drops through an opening in the plate which forms the side of the seed-holder. The rapidity of discharge is perfectly controlled by wheel-work, which causes the axle to revolve slowly or fast at pleasure. The seed-holder is divided into two parts by the wheel, as shown by cross-section in Fig. 40; one part containing wheat, barley, and other medium-sized grains, and the other for corn, peas, and the larger seeds. This figure shows the opening in the side-plates, through which the grain is discharged. As these two divisions must be used on separate occasions, the apertures between them and the hopper are opened and closed at pleasure by a sliding bottom with a single movement of the hand. This sliding bottom is shown in Fig. 41, and forms hoppers with sloping sides down which the grain passes. The ends of the tubes, which are shod with steel, are made to pass any desired depth into the mellowed soil, and form the drills for the seed, which is immediately covered by the falling earth as the drill passes.

In Figs. 42 and 43 is shown the "force-feed" device. The seed is delivered from the internal flange of the feed-wheel. Fig. 42 exhibits the feed for wheat and small grain, and Fig. 43 the same for

42.



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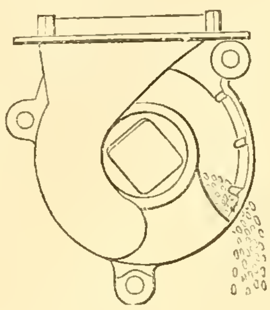

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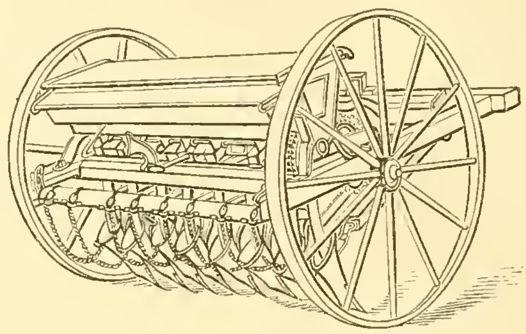
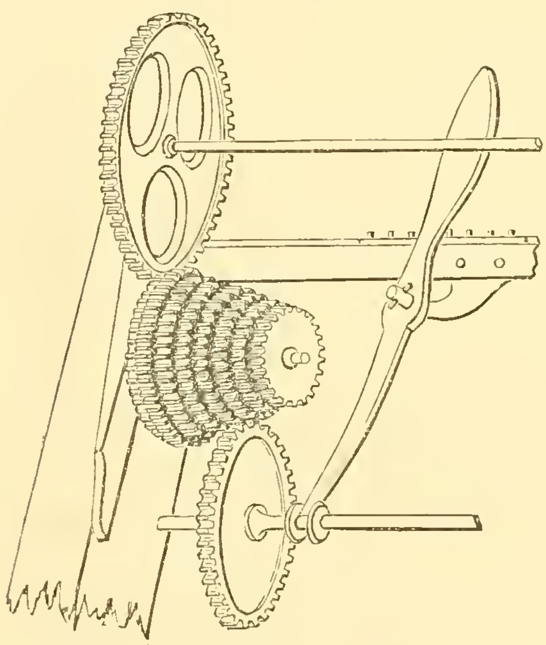


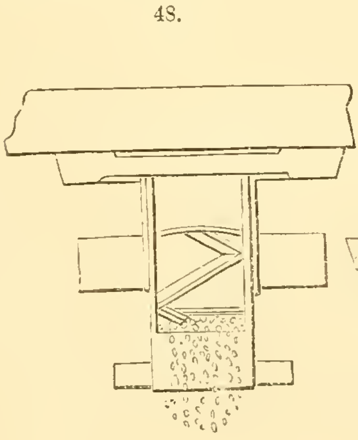
corn or coarse grain. The flange serving as a bottom for the distribution, the grain rests upon it; consequently, when the wheel is revolved, the seed travels exactly with it, thereby insuring the flow of grain to be in a steady, unbroken stream. The two casings, as shown by the cuts, between which the feed-wheel revolves, forms the outer walls of a complete measuring channel, or throat, through which the grain is carried by the rotary motion of the wheel, thus providing the means of measuring the seed with as much accuracy as could be done with a small measure. The quantity sown per acre is governed by simply increasing or diminishing the speed of the feed-wheel.

45.



In Fig. 44 is represented Kuhn's grain-drill, in which the change of speed in the feeding-device is altered by a system of cone-gearing shown in Fig. 45. The lower gear-wheel may be adjusted to mesh into such of the cone-gears as is required in accordance with the amount of seed to be deposited. The mode in which the grain is fed by a positive mechanical movement is exhibited in Figs. 46 to 49. Fig. 46 shows a feed-wheel, Fig. 47 a sectional view of wheel and cap, and Figs. 48 and 49 the delivery of the grain. In Fig. 50 is represented a potato-planting machine. The cut potatoes are placed in the hopper shown. Secured upon the axle is a cast-iron disk, around the periphery of which a number of holes are made in order that the cups may be fastened thereon, at any points or at any distances apart. As this disk revolves, the cups, which are turned rearward, enter the hopper from beneath, passing through an orifice protected by bristles, which serve to prevent the escape of the seed. The cups thus become filled As they are carried on out of the hopper by the disk, they pass through a box, also shown larger at one side. The sides of this attachment are

48.



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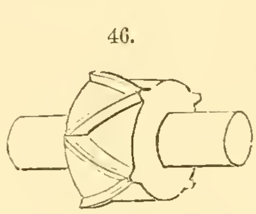

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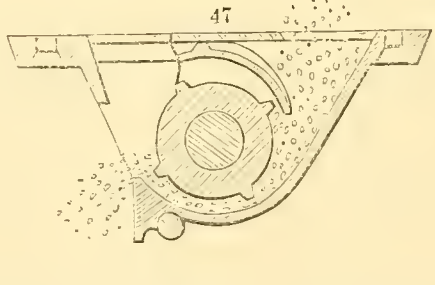

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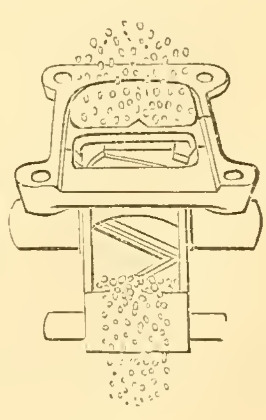
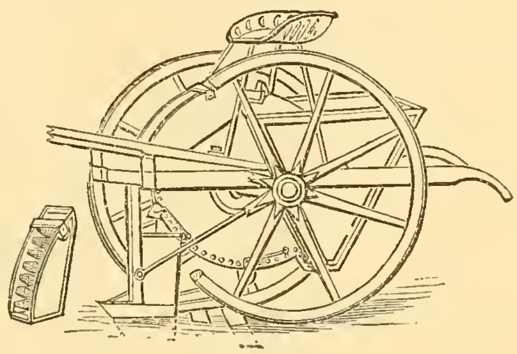


fitted with bristles, which, while offering no resistance to the passage of the cup, retain the seed in the same as it is reversed by the rotation of the disk. As soon, however, as each cup emerges from

between the bristles, its contents drop out—directly, however, into the drill made by the opening plough. Wings in rear of the latter, as the machine advances, replace the soil in the furrow, completing the planting. The knives in the cutter divide the seed into pieces of uniform size, and thus the constant filling of the cups is rendered more certain.

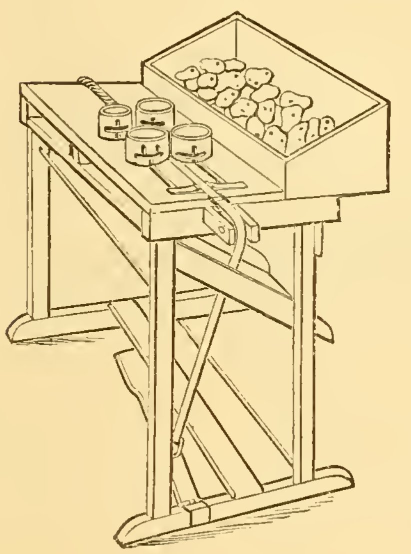
50.



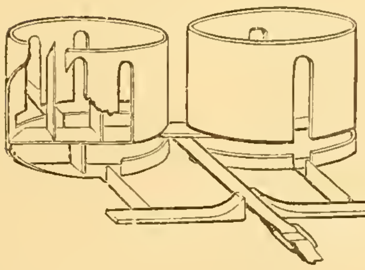
Figs. 51 and 52 represent an apparatus for cutting potatoes before planting. They are placed in the tubes shown on the table, across which a strap passes, thence over a pulley, and finally is attached to a treadle. On the upper side of the strap are bolted horizontal blades (see enlarged view, Fig. 52), which carry one or more vertical cutters on the portions contained within the peripheries of the tubes. These tubes, it will be seen, are slotted in order to allow all the blades to be drawn through them, an operation effected through the strap and treadle already referred to. By increasing the number of vertical cutters in any tube, the number of pieces into which the potato is divided is of course augmented. The system of knives is connected by bars underneath the table, secured to vertical arms extending down through slots in the same.

In operation, after the potatoes are deposited, one in each tube, pressure upon the treadle carries the knives through them; and thus divided, they fall through apertures beneath the tubes, upon an inclined plane, and into any vessel placed for their reception.

51.



52.

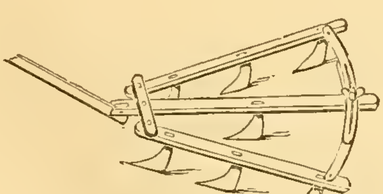


3. *Implements for the Cultivation of the Plant.*

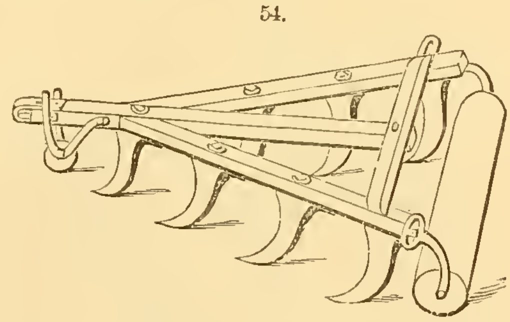
*Cultivators.*—The name cultivator has been applied to a class of implements which is adapted to perform the various agricultural operations necessary to the cultivation of the crop. Properly speaking, the term should imply that its duties commence after the crop is above the ground; but, unfortunately, it has been applied to machines employed in preparing the ground for the reception of seed, which, so to speak, trench upon the duty of the harrow. The ordinary duty of the cultivator, however, is to loosen the earth, destroy weeds, and in some cases to gather the surface earth and leave it around the growing plants or crop. It follows, then, that to admit of the use of the cultivator, the crop must be sown or planted in drills or rows. Cultivators are made in various forms to suit the duty required. When they operate between two rows they are termed single, and when between three rows, double cultivators. Those which provide a seat for the driver are termed sulky-cultivators, while those not so provided are simply "cultivators," and are usually distinguished by an additional term indicating the kind of crop they are intended to cultivate. Thus we have "corn-cultivators," "cotton-cultivators," etc. Double cultivators are arranged so that the outside teeth may be adjusted in width to suit the width of the rows of the crop. In Fig. 53 is shown a hand-cultivator, the two outside rows of teeth being adjustable in width to suit the width of the crop-rows by means of the slotted stays in the rear, which are held by the set screw shown.

In Fig. 54 is represented a cultivator having a gauge-wheel adjustable upon the draught-beam, and also a roller. By these devices the depth at which the implement works in the ground is adjusted. The cultivator shown in Fig. 55 has iron side-beams so curved that, as they are expanded or contracted by loosening the iron keys that confine the teeth in their places, the latter are moved forward or back to a point that will again cause them to work parallel with the centre-beam, and at equal distances from the others.

53.



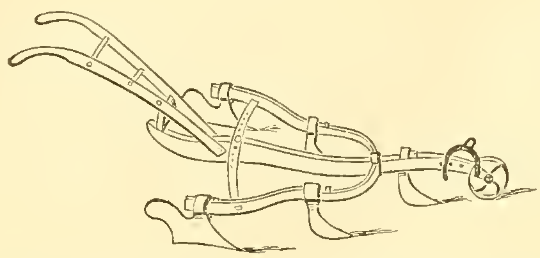
54.



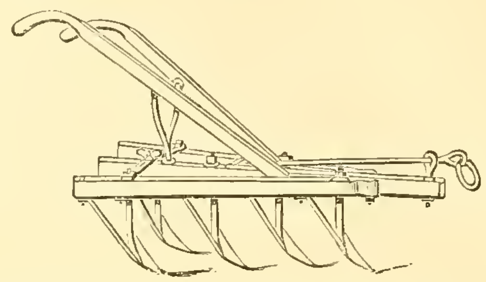
There is also one pair of moulds calculated to work in the rear, in form like small ploughs, throwing the earth in opposite directions, and fitting alike both side-beams; they may be placed to throw the earth to or from the centre, or rows of vegetables.

The cultivator shown in Fig. 56 is adapted to loosen the surface of the soil and destroy weeds. The draught-rod is connected to the centre of the beam to render the operation of the machine steady,

55.

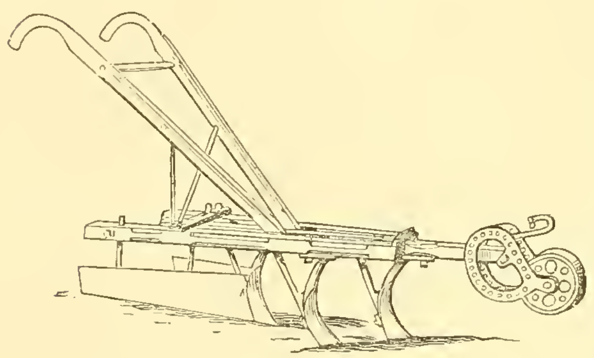


56.



and facilitate the regulation of the depth to which the teeth enter the soil. Fig. 57 is a cultivator and hiller. The soil loosened by the teeth is thrown against the plants by a rear-share. The width of the hiller and of the teeth is adjustable to suit the duty. Fig. 58 represents an improved wheel-cultivator operating between rows of corn. The shovel-frame is pivoted to the axle, and the handles are attached on each side the ploughs, when not in operation are suspended from the hooks shown. For ploughing out between narrow rows the ridging or double-mould plough represented in Fig. 59 is used. It is also employed for opening drills to plant potatoes. Fig. 60 is a double-mould plough or cultivator for sugar-cane. The mould-boards are made to expand to suit the width of the rows. The double share cuts off a surface-slice of the soil, and the wings or mould-boards throw the same up to the cane-plants. Fig. 61 is a four-furrow plough of English construction, designed for steam-cultivation, and the notable feature in it is the admirably simple means provided for adjusting the widths of the furrows. The implement has the rigid frame which is so essential in steam culti-

57.



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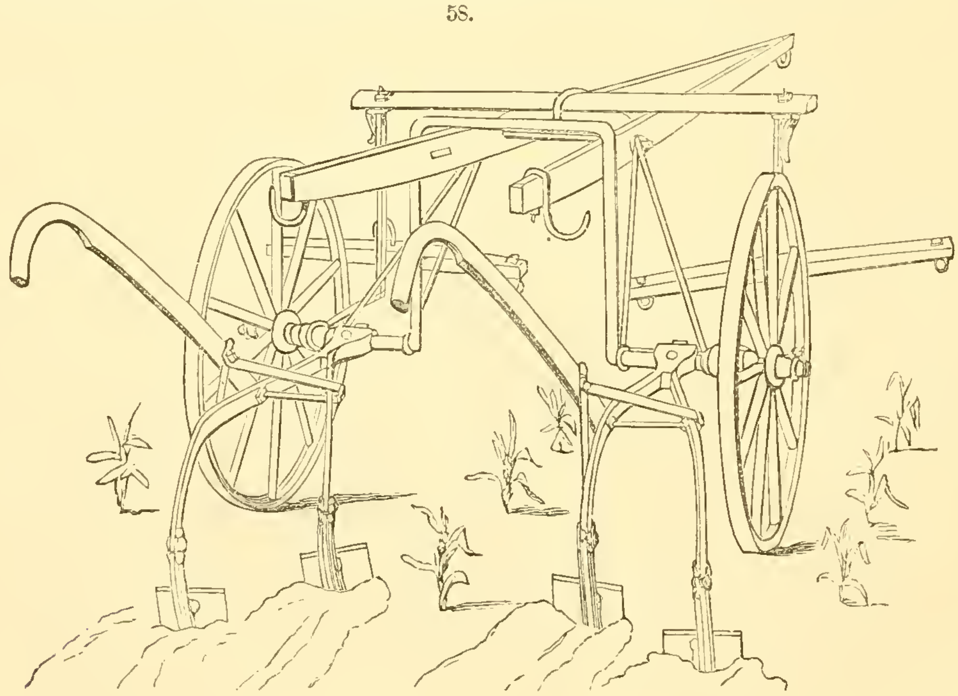

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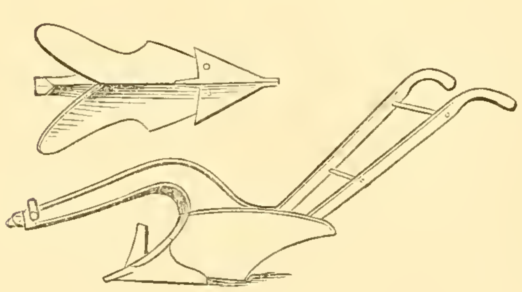
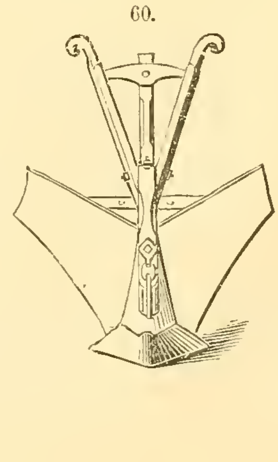


60.



vating implements, while the alteration of the width of the furrows is effected by means of wedges, which throw the ploughs at different angles to the frames. The employment of wedges in this way does away with the necessity for bolts or screws, and makes a thoroughly rigid fastening, while at the same time every facility is afforded for adjusting the width of furrow very quickly.

61.

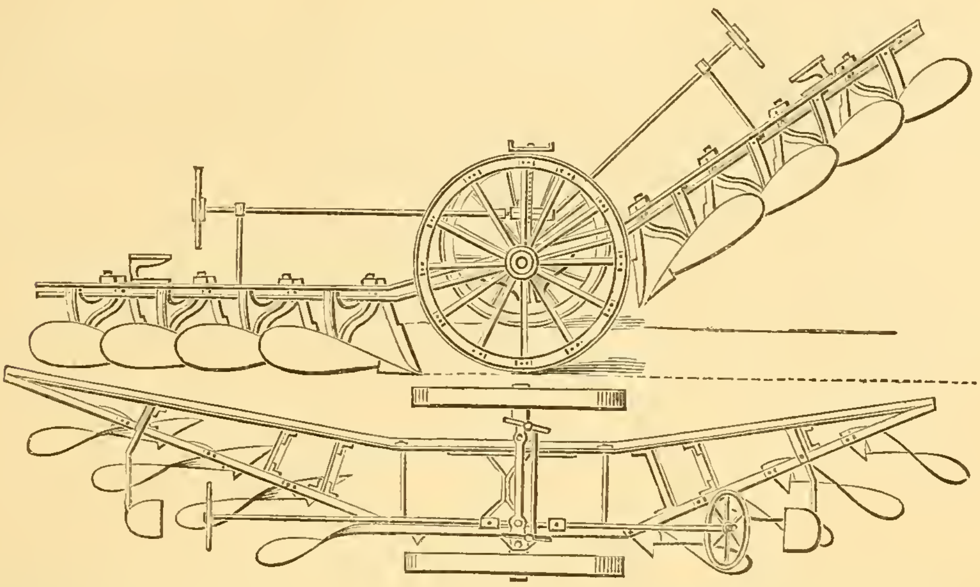
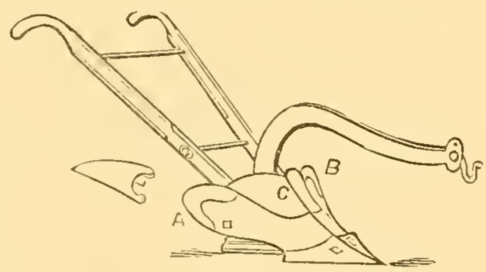


Fig. 62 is a type of the cultivators similar in construction to the double-mould-board plough. The object is to throw the earth on each side, the wings *A B* at the sides being provided to alter the width of the mould to suit that of the cross-rows. The piece *C* is also removable, so that part of the earth may, if desired, fall between the moulds instead of being delivered at the sides.

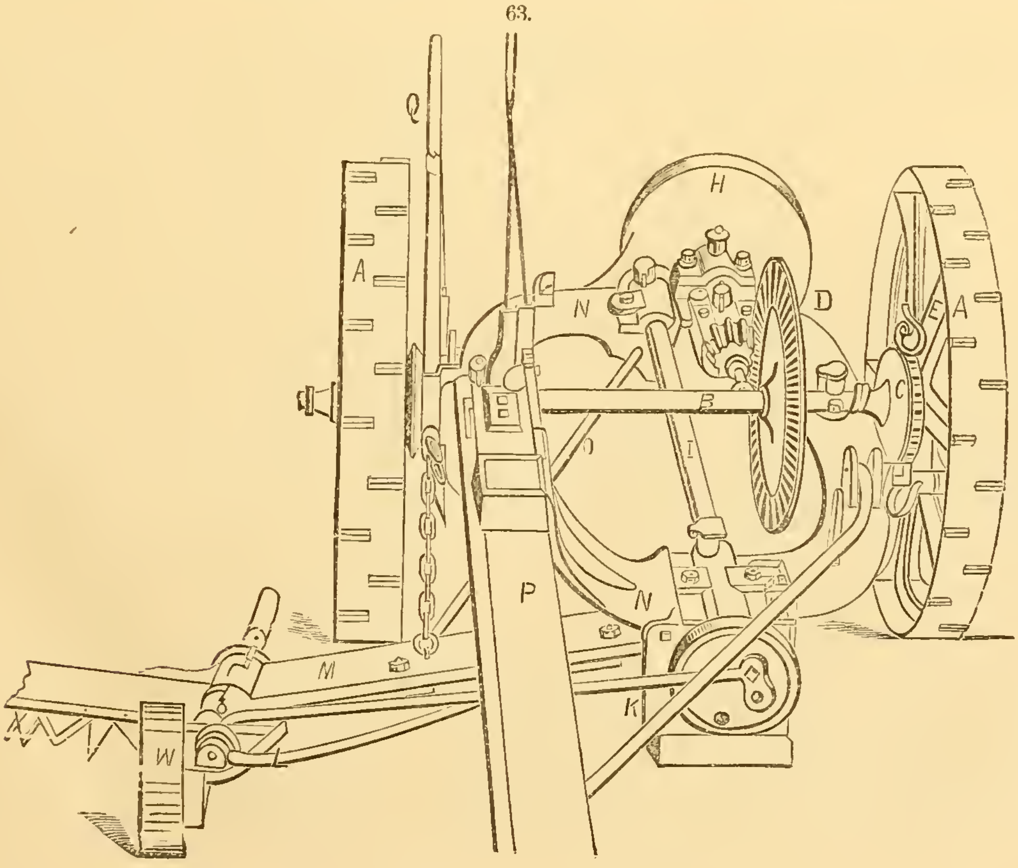
62.




4. *Implements for gathering Crops.*

*Mowers.*—The essential parts of a mower are suitable driving-wheels upon which it travels, and from which motion is transmitted to the cutting apparatus; a main frame supporting the mechanical movements; the cutting apparatus consisting of a finger or cutter bar and a reciprocating scythe; levers or handles by means of which the driver can put the machine in or out of gear, and lift the cutting apparatus to pass obstructions; jointed or flexible connections between the finger-bar and

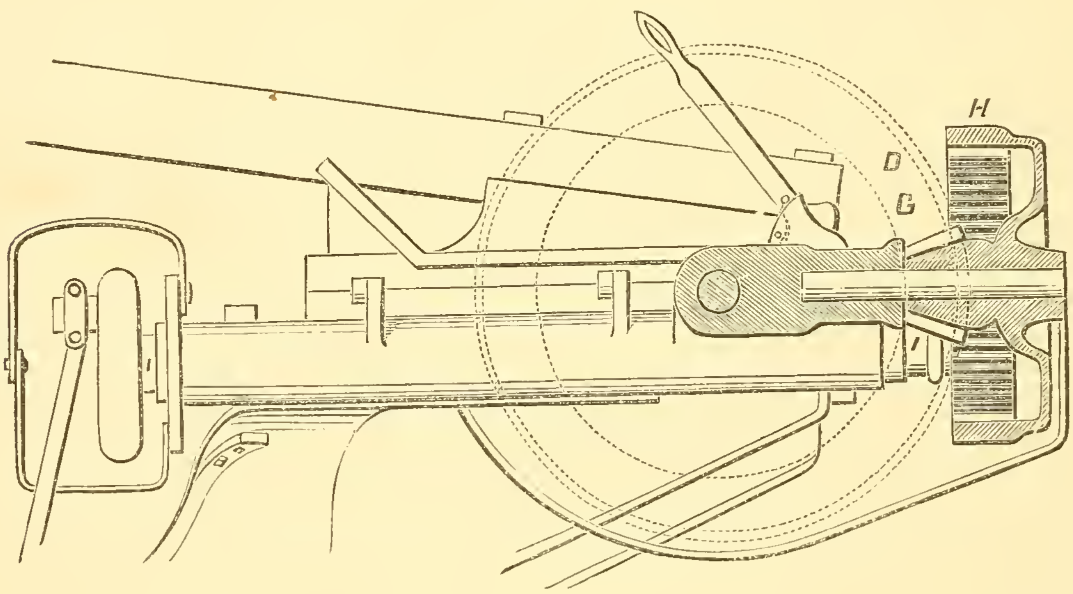
63.



frame, allowing the cutting apparatus to conform to the undulations of the surface of the ground independently of the main frame, and admitting of the folding over of the cutting apparatus on to the frame when traveling on the road so as to stow it out of the way in a compact shape; appliances at each end of the finger-bar for regulating the height of the stubble, and mechanical means of throwing the mechanism operating the cutter-bar in or out of motion. The diameter of the driving-wheels (*A*, Fig. 63) is usually about 30 inches. Hence it follows that one revolution of the wheel carries the machine forward 94.28 inches. The scythe sections project forward 2 inches, so that they must have a sufficient number of vibrations, which (multiplied by the 2 inches) will cut over all the ground traversed. Now, as the machine represented has 51.6 vibrations to one revolution of the driving-wheel, the cut made equals (51.6 multiplied by 2 equals 103.2, which less 94.28 equals) 8.92 inches more than the actual distance traveled by the machine. These vibrations are obtained by multiplying-gear which cause the shaft driving the scythe (through the medium of a crank-disk and connecting-rod) to revolve the necessary number of revolutions faster than the wheels *A*.

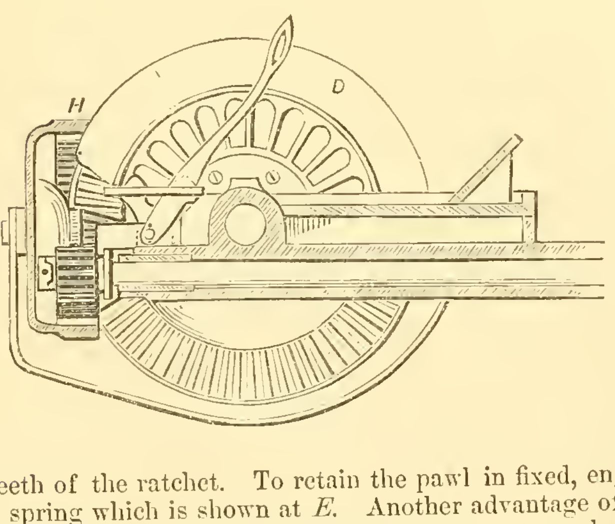
In Fig. 63, *A A* are the wheels upon which the machine travels, the lugs or projections shown upon the periphery of each being provided for the purpose of enabling the wheels to take a firm hold of the ground. This is necessary, because the reciprocating motion necessary to the cutting-knives is obtained either by gear-wheels attached to the shaft upon which the wheels *A A* revolve, or by the said wheels themselves containing an internal gear-wheel. In either case the gear or tooth wheel actuates the parts which operate the cutter-scythe. Hence it follows that if the wheels *A A* were to slide over the ground and not revolve, the operation of the scythe would cease, and the ma-

64.

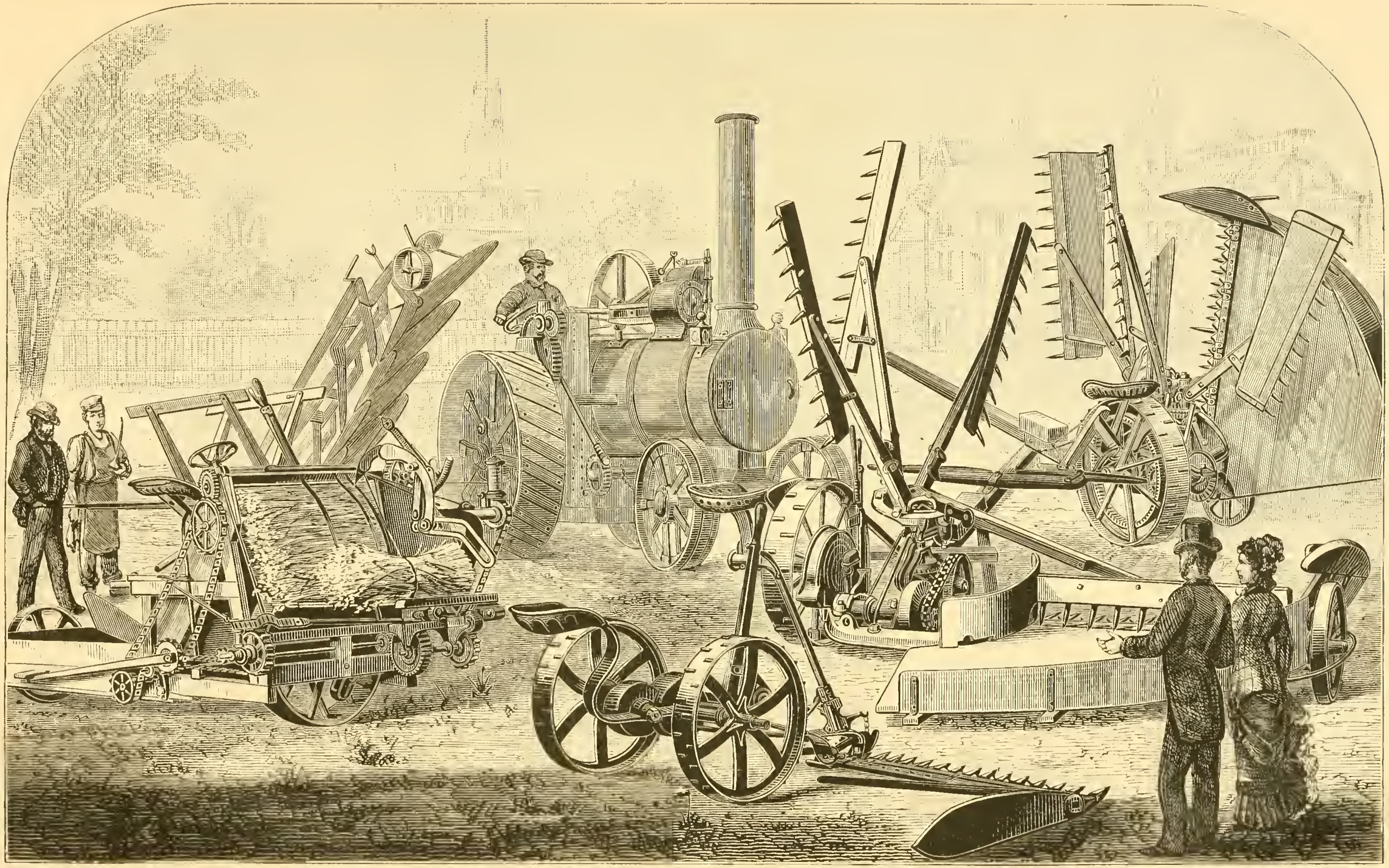



chine would pass over the herbage without mowing it. The framework carrying the mechanical movements necessary to the operation of the machine is carried by means of suitable bearings upon the axle connecting the wheels *A A*, and upon this framework there is provided a seat for the operator. The levers, or handles, by which the operator throws the cutting-knives into or out of operation, or raises or lowers the cutting-device, are convenient to the hand. The machine shown in Figs. 63, 64, 65, and 66, is known as the Buckeye mower, the driver's seat being removed to show the arrangement of the mechanical parts the more distinctly. The wheels *A A* are not, in the mower under consideration, fast upon the axle *B*, so that when the machine is in transit to or from the field of operations the wheels revolve independently, and are, therefore, the only parts in motion. When, however, the machine is in position ready to operate they are connected to the axle *B*, in the following manner: Fast to the axle *B* are the ratchet-wheels *C*, and attached to the side of each of the wheels *A A* are two pawls or catches, each pivoted at one end, so that the other end may engage or disengage with the teeth of the ratchet. To retain the pawl in fixed, engaged, or disengaged position there is provided a spring which is shown at *E*. Another advantage of this arrangement is, that when the horses are backing (in which operation they cannot exert much power), they are relieved of the duty of moving the working-gear of the machine.

65.




To drive the shaft *I* (Fig. 63) two methods of gearing have been applied. In the first (Fig. 63) the bevel-gear *D* drives a pinion upon a short shaft having at its other end a pinion geared to the

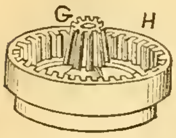


AMERICAN HARVESTING MACHINERY.

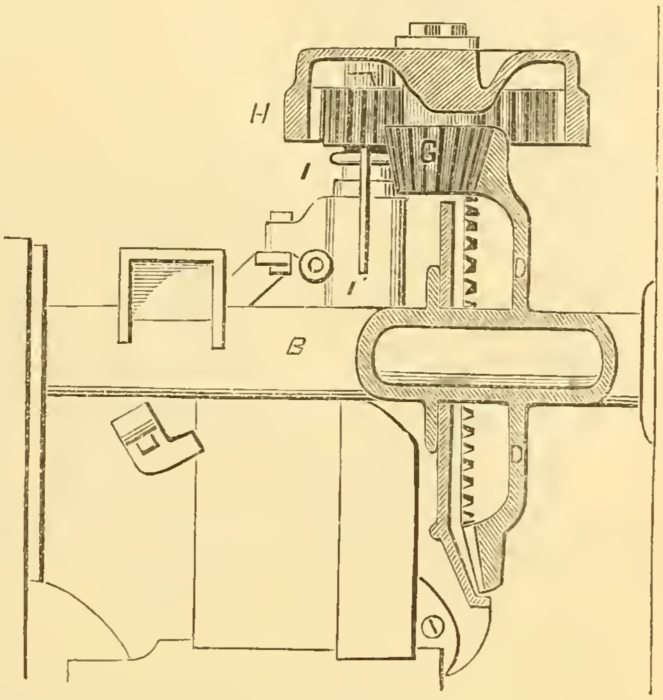
pinion *G* in Fig. 67, which figure is a plan view of the part *H* in Fig. 63. In the second method (Figs. 65 and 66) the bevel-wheel *D* gears direct to the pinion *G*.

Fast upon the axle *B* is the bevel-gear wheel *D* (Fig. 66), which engages with the bevel-pinion *G*, the latter being formed in one casting with the internal gear *H*. This arrangement is constructed in order that, the bevel-gear having 71 teeth, or cogs, and the bevel-pinion having 12 teeth, the revolutions of the latter may be 5.91 to one of the former; and the internal gear *H* having 48 cogs, and the spur-pinion having 11 cogs, the revolutions of the latter are 4.36 times those of the former. Upon the shaft *I*, Fig. 63, at the end *K*, is a crank-disk shown, carrying a crank-pin which communicates reciprocating motion to the rod which is pivoted at that end of the scythe-bar, thus also imparting a reciprocating motion to the latter. Thus it will be noted that the multiplication of scythe reciprocations over the wheel revolutions is obtained in two places: first between the wheels *D* and *G*, and next between the wheel *H* and its pinion. All these wheels are cased in to prevent them from becoming clogged or entangled with herbage. *N N*, Fig. 63, is the iron frame swung by bearings upon the axle *B*, and carrying the parts so far described; *M* is a wrought-iron hinge-bar connecting the cutting-device to the frame *N*, to which it is hinged beneath; while *O* is a brace attached rigidly to *M*, and hinged to the frame *N* at its other end. The joints of the hinges by which both *M* and *O* respectively are attached to the frame *N* are parallel one with the other and also with the shaft *I*, an arrangement which permits of the cutting-device being raised and, lowered without the intervention of a double or universal joint. It is obvious that the cutting-device (as we have termed that part of the machine which consists of the finger-bar, scythe-bar, and the attachments at each end thereof) must be lifted out of the way when it is required to pass over an obstruction, and for this purpose the lever *Q* and its attachments are provided. Upon the draught-pole *P* is the ratchet casting shown in Fig. 68, and upon the projecting pin shown

67.




66.

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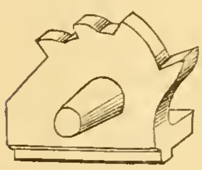
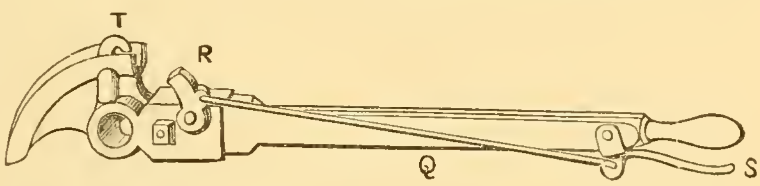


69.

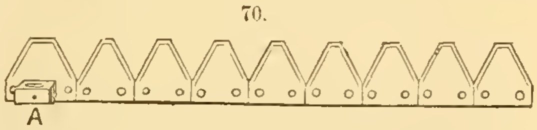



therein fits the hole shown in the lever *Q*, illustrated in Fig. 69; the catch *R* engages and disengages *G* (by operating the latch *S*) with the teeth of the ratchet shown in Fig. 68. To the eye shown at *T* a chain is attached, the lower end of the chain being fast to the hinge-bar *M*, in Fig. 63, so that, by operating the lever *Q*, the bar *M* may be raised to the requisite height and detained there by the catch *R* engaging with the ratchet.

We now come to the cutting-device, which consists essentially of a bar of iron, to which are fixed the cutting-knives, and which is termed the scythe; a bar to which are fixed the stationary cutters, and which is termed the finger-bar; a mechanical device at each end whereby to regulate the height of the scythe from the ground, and means of permitting the scythe to lay in a plane parallel with the surface of the ground.

In Fig. 70 is shown the scythe, the eye at *A* being that to which the rod *K* in Fig. 63 is attached, so as to impart the reciprocating motion; and in Fig. 71 (foreground) is shown the finger-bar, formed of a series of fingers attached to a bar. These fingers serve a fourfold purpose. They are stationary, and have a slot which forms a guide, wherein the scythe reciprocates, and is thus maintained in proper position; the finger-points passing in advance of the knives into the herbage hold the same while it is being cut, and they act as guards to protect the knives from becoming damaged by contact with stones or other foreign substances, while at the same time they hold the lower or stationary knives.

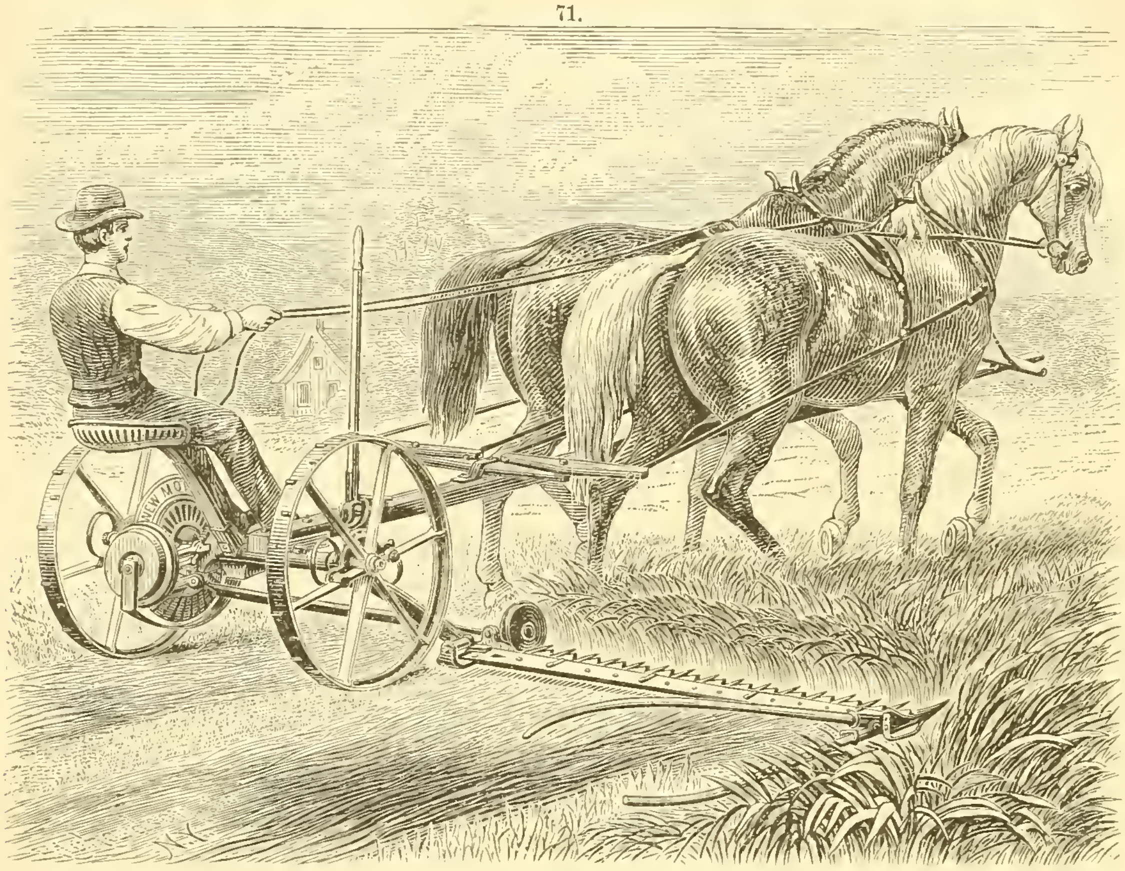
70.




The finger-bar and the scythe are held at each end by castings termed shoes, of which the one nearest the bar *M*, in Fig. 63, is called the inside, and the one at the other end the outside shoe. To these shoes are attached the devices which, when adjusted, keep the guard-fingers the desired height from

the ground. This is accomplished on the inside shoe of the wheel $W$, shown in Fig. 63, which is adjustable for vertical height in a slot provided in the shoe. By raising the wheel $W$ the vertical

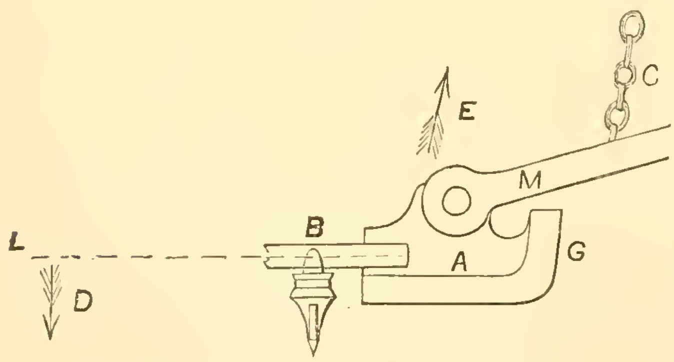
71.



height between the bottom of that wheel which runs upon the ground, and the guard-fingers, is diminished, and *vice versa.* The same result is attained on the outside shoe by adjusting the height of the foot of the same from the finger-bar.

In the outside shoes are also carried the track-clearers shown in Fig. 71, at the end of the bar. These cause the herbage, when mown, to fall clear of that uncut, thus leaving a clear space between the two. In addition, however, the inside shoe performs another and an important duty, as follows: The cutting-device requires to cant or tilt to suit the conformation of the land beneath the guard-fingers, and it follows that the connection between this device and the bar must be such that while the former can follow the above conformation it can yet be lifted bodily to pass an obstruction. These two ends are attained as shown in Fig. 72, in which $A$ is a section of the shoe, $B$ is the end of the finger-bar attached to the shoe, $M$ is an edge-view of the bar $M$ shown in Fig. 63, $C$ is the chain to raise the same, and $G$ is a lug or gag. Now, the distance allowed between the top of the gag $G$ and the underneath face of the bar $M$ is sufficient to permit the finger-bar to lie at any angle necessary to suit the slope of the land; but when it is intended to raise the same to pass an obstruction, the following action takes place: The weight of the cutter-bar is in the direction of the arrow $D$; hence, when the bar $M$ is raised (in the direction of the arrow $E$) by the chain $C$, the outside shoe remains upon the ground until the top of the gag $G$ contacts with the face of the bar $M$, whereupon the whole cutting-device raises up to a height determined by the distance the lever $M$ is moved.

72.



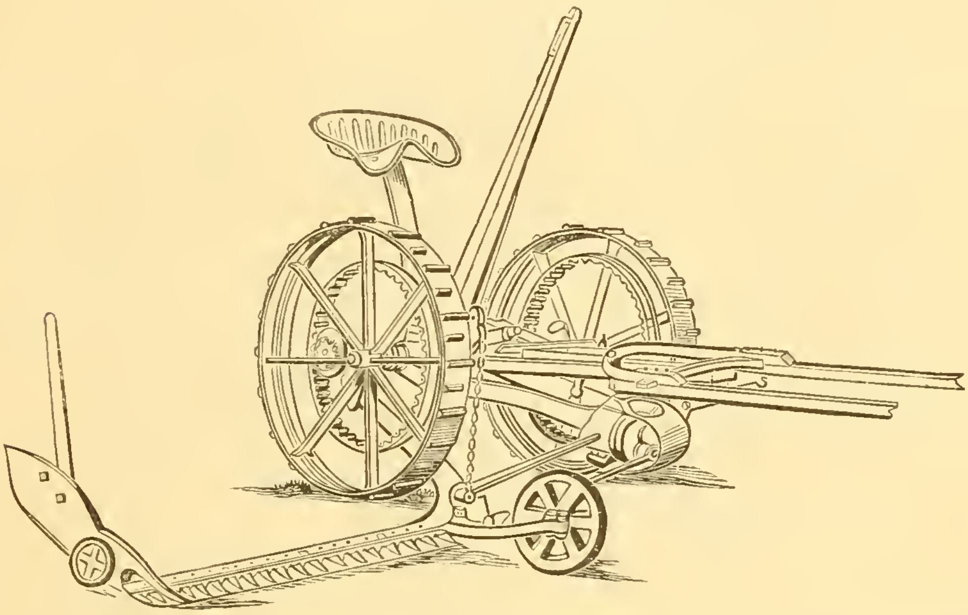

The cutting-device or mowing-part of the machine is shown in Fig. 71. The scythe-knives operate laterally on the finger-guards and above the lower knives. A cutting-edge is given to the knives held in the fingers by beveling off the bottom-face edge, while the cutting-edge for the upper or scythe knives is formed by beveling off the top face at the edges. For cutting grass or other green herbage, the edges of the knives are plain, but for cutting grain the knives are given a sickle-edge—that is to say, the beveled face of the knife is serrated to form fine teeth. The sickle-edged knife will not serve for grass-mowing, but is preferred for grain, because it retains its cutting-edge without grinding, thus saving that labor.

When, however, the grain is to be cut sufficiently near the ground that the knives come into contact with weeds or other green herbage, plain knives must be used, as sickle-knives would become clogged. The cutting angle for scythe sections or knives is about 60°, and for sickle-edges about 40°

The variations in the construction of all mowing-machines consist of mechanical devices and move-

ments, designed to effect the objects herein described. In the machine here illustrated, the mowing is performed in front of the driving-wheels $A$ $A$, while in others it is performed in a line with the axle $B$, and in yet others still farther to the rear of the side. In some cases, also, the frame $N$ $N$, Fig. 63, is made to adjust out of the line of draught, so that the points of the finger-guards may depress toward or cant from the surface of the sward. In all mowing-machines the cutting-device is either made to lift and stand vertical, or else to fold over to the frame of the mower, in order to be out of the way during transportation from place to place.

73.



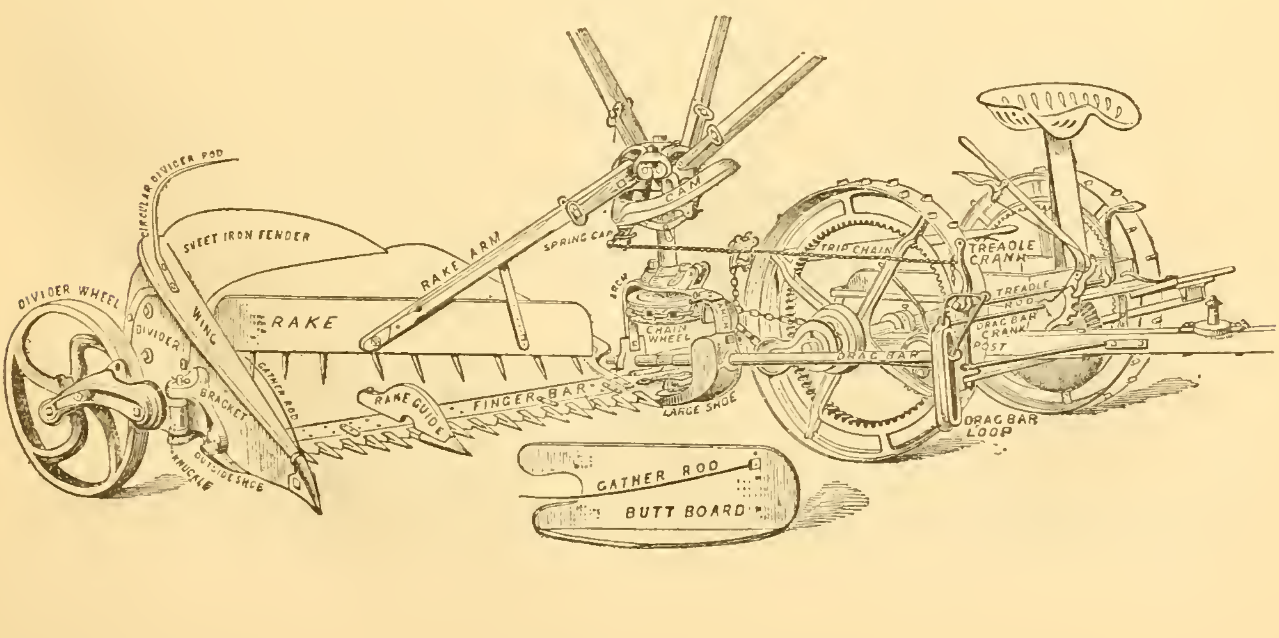
In Fig. 73 is shown Wm. Anson Wood's mower, in which an internal gear-wheel, provided upon the main wheel, drives the cutter-bar.

*Reapers* or harvesting-machines are used for cutting grain-crops. They either deliver the grain to one side in gavels ready to bind into sheaves, or elevate the gavels upon a platform where two operators bind them into sheaves by hand. An attachment is often provided whereby the machine successfully performs the binding of the sheaves automatically with wire before delivering them.

The essential parts of a reaper are: the cutting arrangement, similar in design to that of mowing-machines (except that in many cases sickle-knives in place of plain knives are used); sweep or table rakes to convey the grain to and from the machine; and mechanical means to regulate the delivery of the gavels, so that the size of the same shall be sufficient for binding even in spots or places upon the land where the crop is very light. Many of these machines are constructed so that the various devices for raking, sweeping, gathering, or delivering, may be detached, leaving the machine a simple mower.

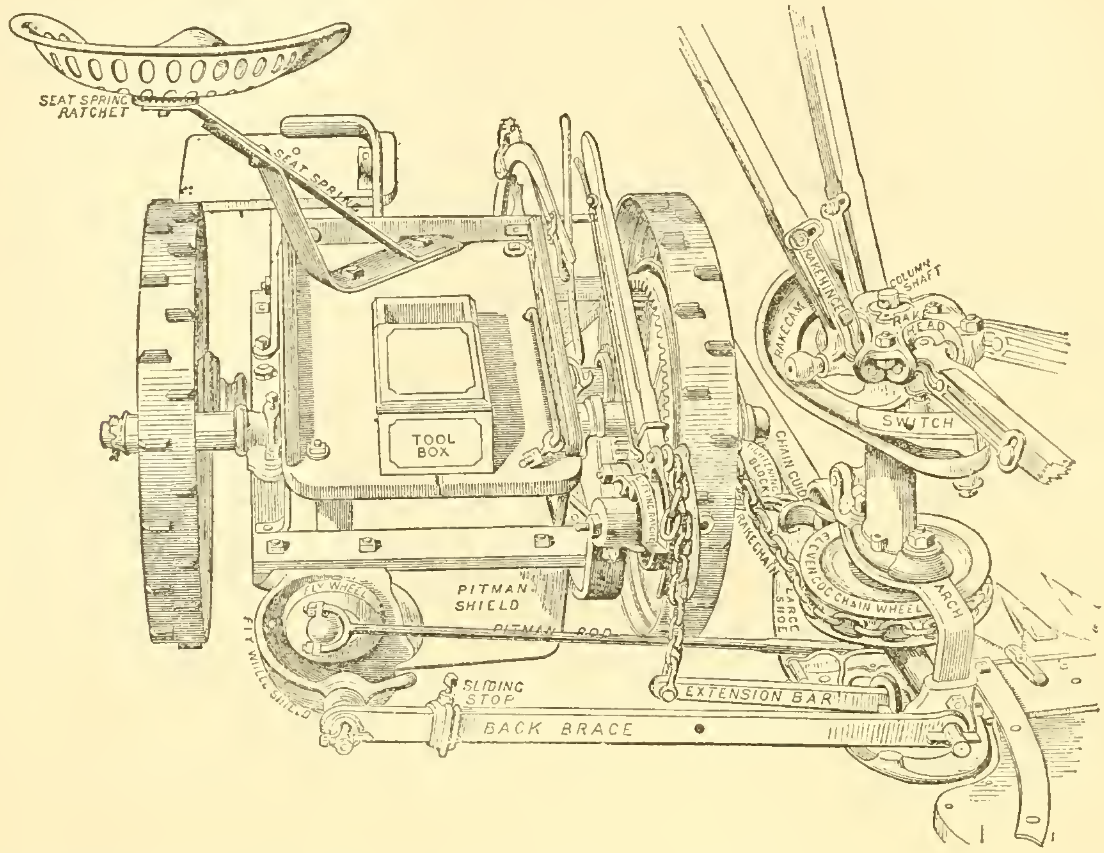
The term "Harvester" originated in the Western States, and was applied to distinguish machines which bound the grain from those which simply delivered it in gavels. In Figs. 74 and 75 is shown the Champion mower and reaper, with the names of the various parts marked thereon. The reaping part of the machine consists of the device above the large shoe, which is for operating the rake-arms and the wooden framework, and its attachments whereon and whereby the grain is gathered and delivered in gavels. The chain-wheel is fast to the upright spindle, to which the rake-arms are pivoted or hinged, and is driven by a chain passing around another chain-wheel attached to the main axle

74.



of the machine. To the rake-arms are attached rollers running upon an inclined pathway termed a cam. The plane of this pathway is arranged so as to lower the rake-arm to, and lift it from, the

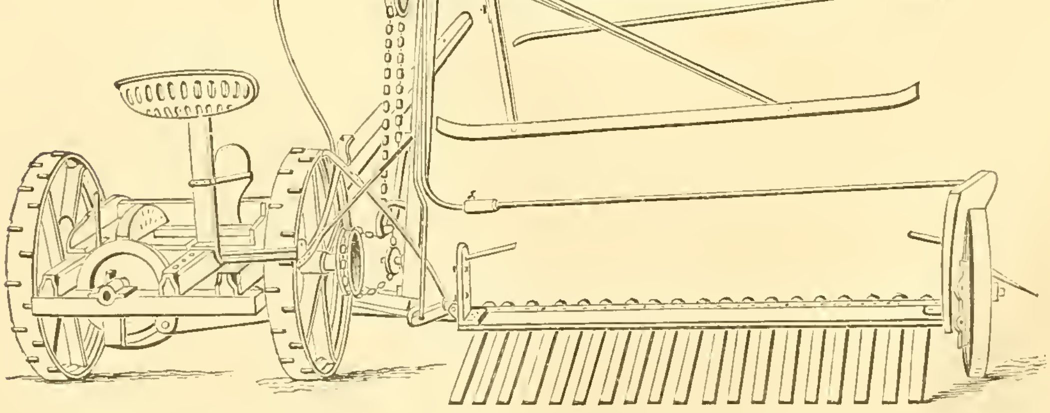
75.




table, to rake the grain on to and off from the table—the rake-guide being provided to prevent the rake from contact with the finger-bar.

The rake-arms may be permitted to sweep a gavel of grain from the table at each descent, or may be made to carry the grain on to the table, and allow it to remain there until sufficient is accumulated to form a gavel, when the rake may be allowed to sweep it off. The arrangement by means of which this is accomplished is the switch shown in Fig. 75, operated by means of the treadle-crank and trip-chain shown in Fig. 74. The switch acts to raise the roller-path, lifting the rake-arm and rake before it has time to rake the gavel from the table. When, however, sufficient grain has accumulated to

76.



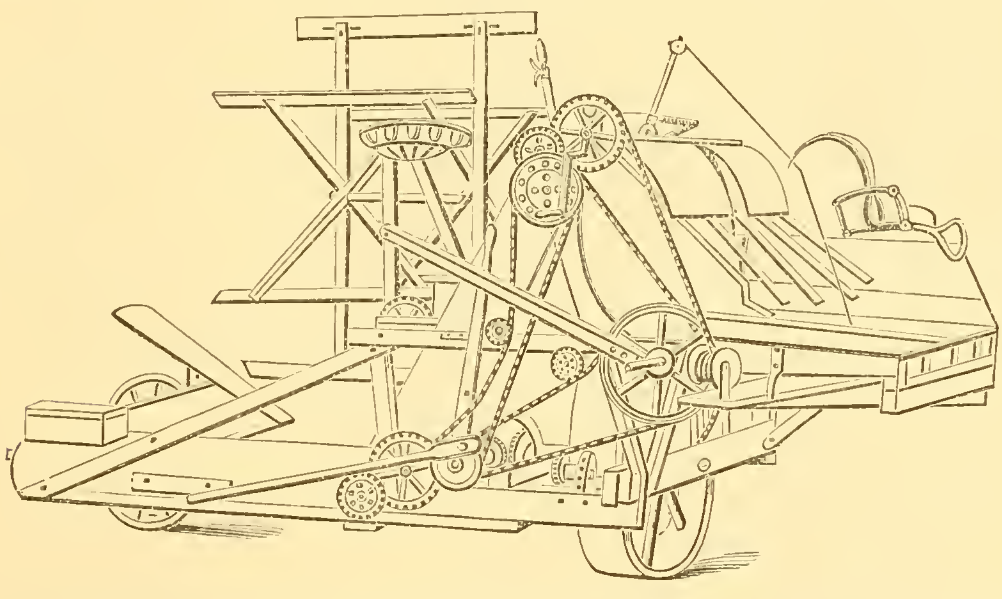
form a proper-sized gavel, the switch moves out of the way, and the rake sweeps the gavel from the table; and in this manner the size of the delivered gavel can be regulated by the operator.

Mr. John Coleman, an English judge at the Centennial Exhibition, says, referring to this class of machines, in his report to the English Government: "A word or two as to table-rakes may not be out of place, seeing that this form of reaper is unknown in England. The ordinary sweep-rake is replaced by a jointed rake, which travels in a given orbit on the table or platform, being driven by universal-joint-and-bevel gearings, the direction of travel being regulated by a cam screened from the grain by a shield. The advantages claimed for this invention are reduction of draught and superior form of the grain for binding. The rake, when uncontrolled, works continuously but can be arrested at any point by a leverage from the driver's foot. This is a desirable feature, allowing of uniform sheaves for a variable crop. The disadvantages appear to be that, as the rake compresses at the corner of the table, there is some risk of shedding when over-ripe; also, that the compact nature of the sheaf interferes with the drying influence of sun and wind, so important when grain is cut in a green condition; and, lastly, the table-rake is not suitable for very heavy crops, especially if the straw is long."

In Fig. 76 is shown the Buckeye mower and reaper, with dropping attachment. In machines of this class a revolving reel instead of sweep-rakes is employed, and the gavels are dropped in the rear of the machine. The duty of the reel is to press the grain to the knives, and hold it while being cut by the scythe. The dropper, as the slotted frame behind the cutter-bar is called, is raised at an angle to collect the grain, and is lowered by hand to deposit the gavel.

The Walter A. Wood binder makes a bundle or sheaf to every ten feet, if allowed to work automatically. The binder can be removed from the machine, and the grain bound by hand upon tables

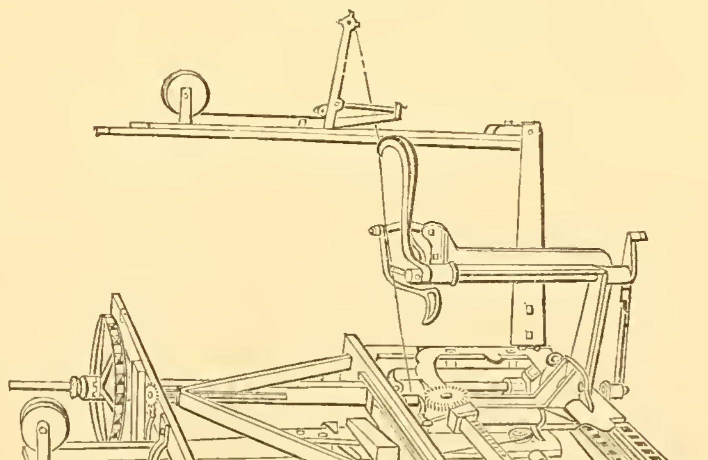
77.



attached for the purpose. The amount of duty claimed for a Walter A. Wood harvester with binding attachment is, with fair grain on fair ground, from ten to fifteen acres per day.

In Figs. 77 and 78 is shown the McCormick harvester with self-binding attachment, the latter showing the binding attachment detached.

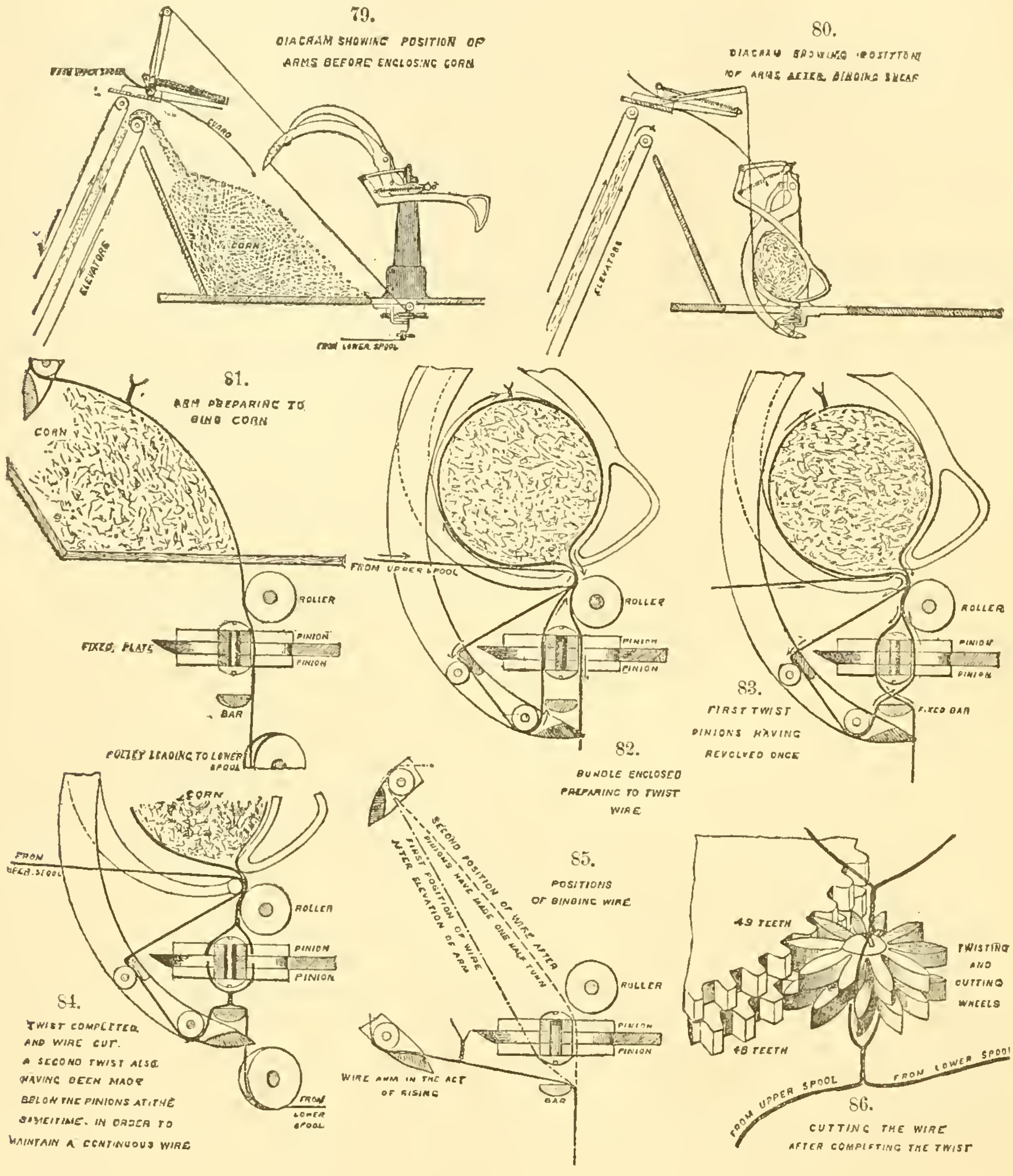
78.



The details of the McCormick sheaf-binder are represented in Figs. 79–86.

The binding apparatus is fixed at the side of the reaping machinery. The grain as cut is delivered by an endless band to the elevators, shown in Fig. 79, by which it is raised and delivered under the guard on to the platform. Fig. 79 also shows the general form of the binding-arms and their position before inclosing a sheaf. The standard carrying the binding-arm has a reciprocating movement imparted to it, by which it is moved from the position shown in Fig. 79 to the various other positions shown successively in Figs. 80, 81, 82, etc. To put the machine into work, the wire from the upper spool is threaded into the main arm, as shown, and jointed to the wire from the lower spool brought up from under the twister, as shown in the upper part of Fig. 85. The main arm may now be supposed to have moved to the position shown in Fig. 81, and is about to descend through the slot in the platform, and to take the position shown in Fig. 82, at which position the thumb *I*—seen also in other figures—has moved and passed the other part

of the wire, or that from the upper spool, in between the teeth of the twister, so that the two parts of the wire are between opposite teeth in the twister. The standard now begins to return to the




79. DIAGRAM SHOWING POSITION OF ARMS BEFORE ENCLOSING CORN

80. DIAGRAM SHOWING POSITION OF ARMS AFTER BINDING SHEAF

81. ARM PREPARING TO BIND CORN

82. BUNDLE ENCLOSED PREPARING TO TWIST WIRE

83. FIRST TWIST PINIONS HAVING REVOLVED ONCE

84. TWIST COMPLETED AND WIRE CUT. A SECOND TWIST ALSO HAVING BEEN MADE BELOW THE PINIONS AT THE SAME TIME, IN ORDER TO MAINTAIN A CONTINUOUS WIRE

85. POSITIONS OF BINDING WIRE

86. CUTTING THE WIRE AFTER COMPLETING THE TWIST

position shown in Fig. 79, and in its rectilinear movement the teeth of two wheels shown in Fig. 86 engage in a rack by which they are revolved, and in their revolution they move the two steel wheels which form the twister and the cutter, a differential movement being given to them by the difference in the number of teeth in the main wheels, so that the twister-teeth gradually overlap after several revolutions by one revolution of the main wheels. As seen in Fig. 82, the sheaf is inclosed, both parts of the wire are in the twister-teeth, and the latter now begin to revolve.

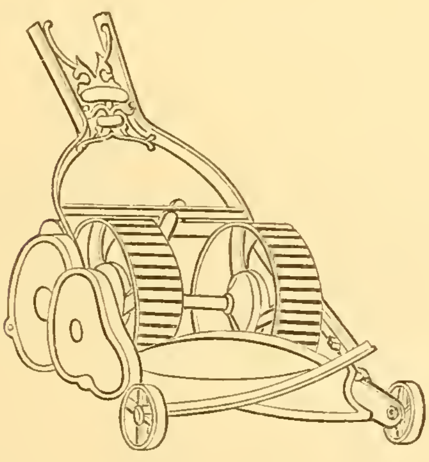
Fig. 83 shows the position after the first twist, and Fig. 84 shows the twist completed, and the wire cut off, the wheels having assumed the position shown in Fig. 86, and the standard having nearly returned to the position of Fig. 79. Fig. 80 shows the position of both arms after the sheaf is bound, but before it is released. Each successive sheaf passes the last one off the platform. Now, it will have been seen that the wire has been joined by twisting both above and below the twister, so that, though cut off in one place, the wire is by the join continuous from lower to upper spool, as seen in Fig. 84. When the arm begins to rise again, the lower wire, as seen in Fig. 79, is pulled to the position seen in the lower part of Fig. 85, and as the arm still rises, the wire is pulled in between the twister-teeth, as shown by the light-dotted lines. Now it becomes necessary to get the wire to the position shown in the dark-dotted lines, or to that shown in Fig. 81, and to effect this the twister-wheels receive a half-revolution, obtained by the meeting of a projecting arm and two studs on the main cog-wheels, during the latter part of the return-movement of the standard, which it will be seen carries all this mechanism. The projecting arm thus gives the wheels a push farther round. The wire is now in the position shown in Figs. 79, 81, and 85, and the whole is ready to recommence the binding operation.

The following is a summary of the dynamometer tests of sheaf-binders made at the Royal Agricultural Society in August, 1877:

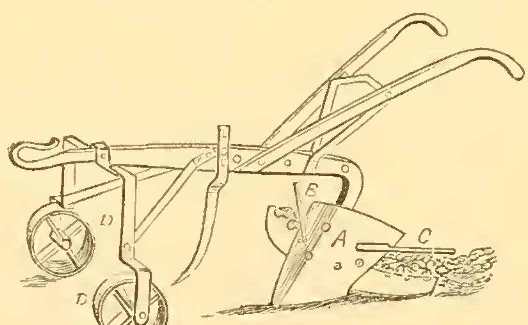
| | Name of Exhibitor in Order of Trial. | | | |
|---|---|---|---|---|
| | C. H. McCormick. | Walter A. Wood. | D. M. Osborne & Co. | Averages. |
| Width of cut, with lay | 58 in. | 50 in. | 55.2 in. | |
| " against lay | 52 in. | 61 in. | 62 in. | |
| " average | 55 in. | 55.5 in. | 58.6 in. | |
| Height of stubble | 8 in. | 6 in. | 7 in. | |
| Side-draught, with lay | 35 lb. | 15 lb. | 35 lb. | |
| " against lay | 25 lb. | 25 lb. | 37.5 | |
| Mean draught (in lbs.), with lay | 464 | 468 | 486 | |
| " against lay | 471 | 460 | 418 | |
| " average | 467.5 | 464 | 452 | 461 |
| Mean draught (in lbs.), per inch width of cut, with lay | 8 lb. | 93.6 lb. | 8.85 lb. | |
| Mean draught (in lbs.), per inch width of cut, against lay | 9.06 lb. | 7.54 lb. | 6.75 lb. | |
| Mean draught (in lbs.), per inch width of cut, average | 8.53 lb. | 8.45 lb. | 7.8 lb. | 8.26 |
| Mean speed in miles per hour | 3.15 | 3.00 | 3.22 | 3.12 |
| Width of knife | 5 ft. 6 in. | 4 ft. | 5 ft. 6 in. | |
| No. of sheaves cut | 17 | 21 | 18 } 16 } 34 | |
| Total weight of sheaves | 265 lb. | 371 lb. | 250 } 173 } 423 | |
| Mean weight of each sheaf | 15.6 | 17.7 | 13.9 } 10.8 } 12.4 | |
| Foot-pounds of work per lb. of corn cut, or height to which corn must be raised to represent work done in cutting and binding it. | 423.5 | 420.7 | 468 | |

*Lawn-Mowers.*—The use of these machines is indicated by the name. The essential parts of the apparatus, a representative of which is shown in Fig. 87, consist in the wheels and frame, the rotary cutters, and a stationary knife below, and multiplying gearing for transmitting motion from the wheels to the cutters. The construction is such that, when the machine travels in one direction, the

87.



88.



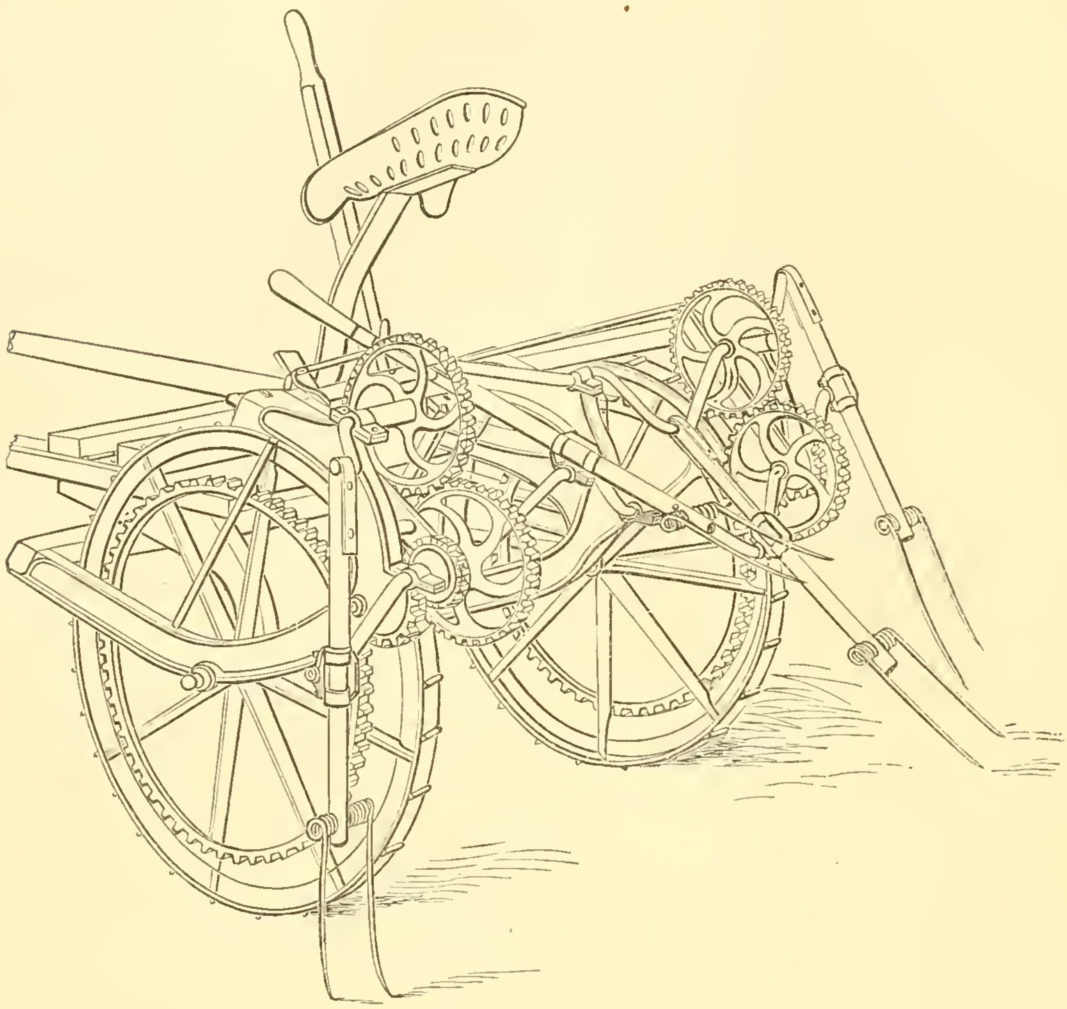

cutters are operated, and when moved in the other they are not. The machine is made in various sizes to adapt it for hand-use, or to enable it to be drawn by a horse.

*Potato-Digger.*—One form of this apparatus is illustrated in Fig. 88. On the under and near side of the centre plough $A$ is an adjustable bar of steel, having sharp-edged wings, and fastened to this throughout its whole length, which is more than the full breadth of the furrow, are a number of looped and branched chains, two feet or more in length, which drag on the bottom of the furrow, breaking up and stirring the earth that falls upon and through them, and bringing the potatoes to the surface. This chain-bar may be placed higher or lower, as may be desired. A coulter, blunt-pointed and round-edged, is attached to the beam, and opens the hills at the right-hand side, clearing away the bines, and placing them over to the left of the plough, which follows, turning the hills up. The two rods $B$ $C$ are sufficiently high to permit the earth to pass between them, while they cause the weeds to pass to one side. The wheels $D$ $D$ steady the implement, and also serve as gauge-wheels to regulate the depth to which the plough enters the soil.

*Hay-tedders* are used to turn the hay as it lies on the meadow, in order to dry it preparatory to stacking. In the tedder illustrated in Fig. 89 the main wheels contain a gear-wheel driving, through the medium of pinions, cranked shafts carrying forks. Each fork is connected at its centre and at its end to a crank upon the upper, and one upon the lower, shaft. The upper shaft is operated by gears connected with the lower one. The whole framework carrying the forks and gearing swings upon the bearing, supporting it on the axle. The draught-frame is secured to the latter by separate

bearings; hence to alter the distance at which the forks approach the surface it is necessary only to change the position of the fork-carrying frame with relation to the draught-frame. This is accom-

89.



plished by the lever shown above the driver's seat. The motion of the forks is closely similar to that performed by hand in tossing the hay. English machines usually have two separately-rotating frames carrying forks, each fork occupying one-half of the width between the wheels. The direction of motion of the forks may be reversed, so that, after the hay has been strewed in the usual way, it may be thrown backward. A machine of this class is shown in Fig. 90.

90.

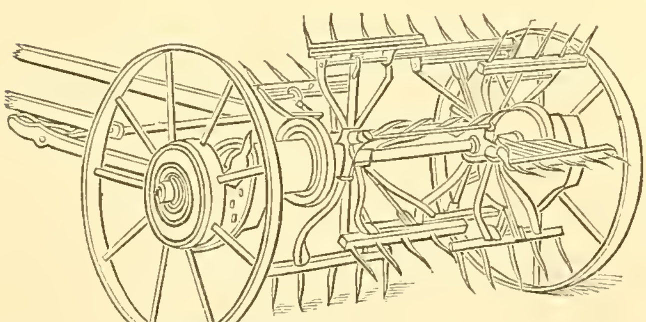
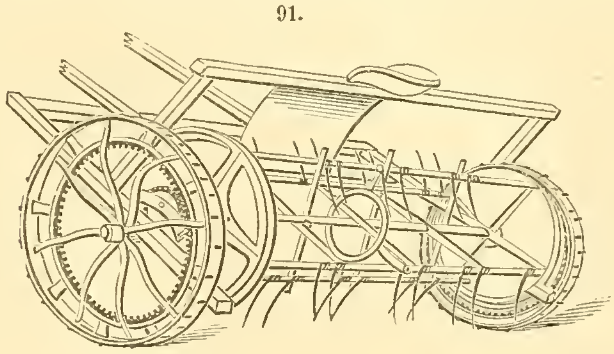


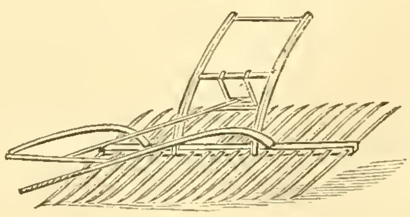
Fig. 91 represents an American hay-tedder having revolving forks. The fork-shaft is revolved by multiplying gear from the wheel-axle. It is furnished with sixteen forks, attached to a light reel in such a manner that they revolve rapidly, with a rotary, continuous, and uniform motion. It never clogs, may be easily backed, and readily passes over ordinary obstructions, without any attention on the part of the driver.

Hay-tedders should be used on the meadow about three times a day, which will enable the farmer

91.



92.

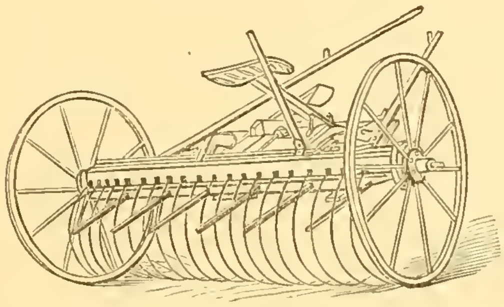


to cut his crop in the morning, and draw it in the same day; giving him, also, more uniformly dried and better hay.

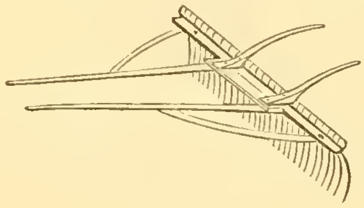
*Horse hay-rakes* gather the hay preparatory to its removal from the meadows. That represented in Fig. 92 may be used without lifting the rake or stopping the horse. It has a double row of teeth, pointing each way, which are brought alternately into use as the rake makes a semi-revolution at each forming windrow, in its onward progress. They are kept flat upon the ground by the pressure of the square frame on their points, beneath the handles; but, as soon as a load of hay has collected, the handles are slightly raised, throwing this frame backward off the points, and raising them enough for the forward row to catch the earth. The continued motion of the horse causes the teeth to rise and revolve, throwing the backward teeth foremost, over the windrow. In this way each set of teeth is alternately brought into operation.

An improved form of rake is represented in Fig. 93. It is arranged with a sulky, so that the operator can ride. The spring-teeth gather the hay and retain it until the driver, by pulling the vertical lever, lifts the teeth and discharges it. The horizontal bars projecting through the teeth keep the hay from rising with them, thus insuring its complete discharge. Fig. 94 shows another form of spring-tooth rake, the teeth of which are made of stiff, elastic wire, on the points of which

93.



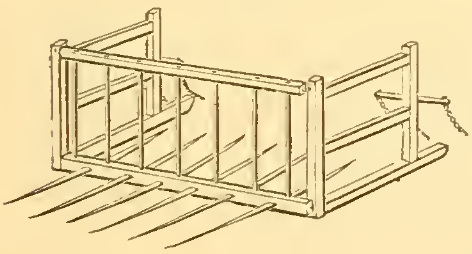
94.



the rake runs; they bend in passing an obstruction, and spring back into their place again. The rake is unloaded by simply lifting by the lower handles, the upper ones being intended for holding and guiding; the rake is light, and about one-half the weight sustained by the horse.

*Hay-sweeps* are essentially large, stout, coarse rakes, with teeth projecting both ways, like those of a common revolver; a horse is attached to each end, and a boy rides each horse. A horse passes along each side of the windrow, and the two thus draw this rake after them, scooping up the hay as they go. When 500 lbs. or more are collected, they draw it at once to the stack or barn, and the horses turning about at each end, causing the gates to make half a circle, draw the teeth backward

95.



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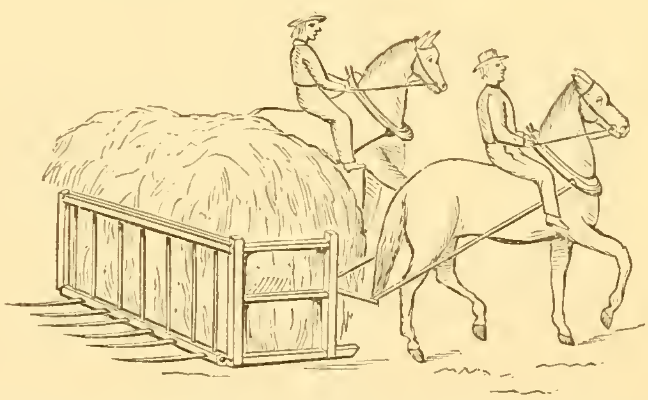
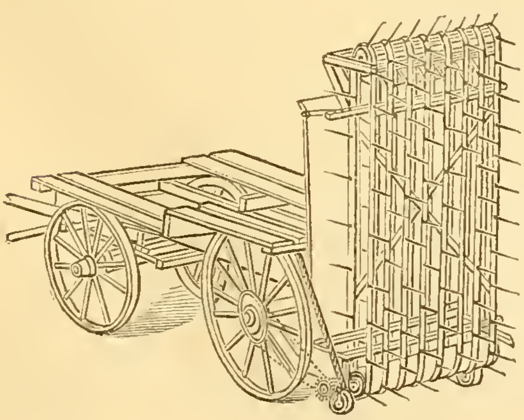


from the heap of hay, and go empty for another load—the teeth on opposite sides being thus used alternately. In Fig. 95 the apparatus is shown separate, and in Fig. 96 in operation.

97.



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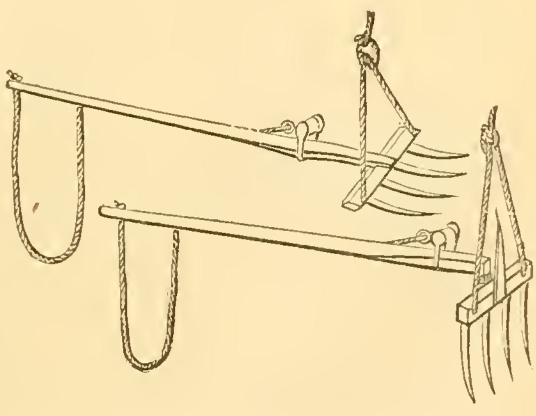
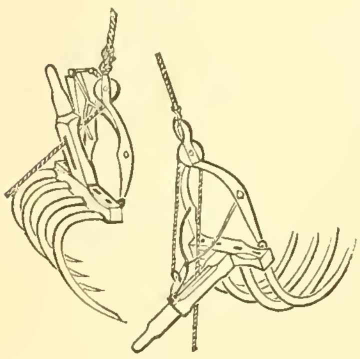


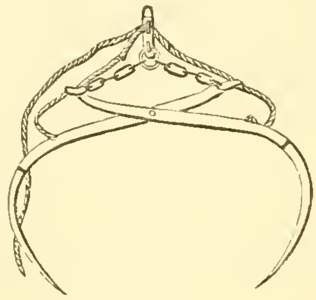
*Hay-loading machines* lift the hay upon vehicles. The Douglas machine, shown in Fig. 97, consists of a frame hinged to the rear of the wagon, and suspended by chains, by which it can be raised and lowered at will. Upon the hinged frame stands an upright frame, carrying rollers at its top and bottom. Around the rollers pass leather belts, armed with steel spurs, which pick up the hay as the wagon passes over it. The lower rollers are rotated by chain-gear from the rear axle of the wagon.

*Horse hay-forks* are also used to facilitate the loading and unloading of hay. Fig. 98 shows Gladding's fork, in which a hinge-joint is placed at the connection of the head and handle, so that at any moment, by a jerk on the cord which passes through a bore in the handle, the fork is dropped, and the load allowed to fall on the stack or wagon, as shown in the lower figure. Another form of fork adapted for lifting hay into barn-windows, etc., is represented in Fig. 99, in which the mode of operation is plainly shown.

99.



100.

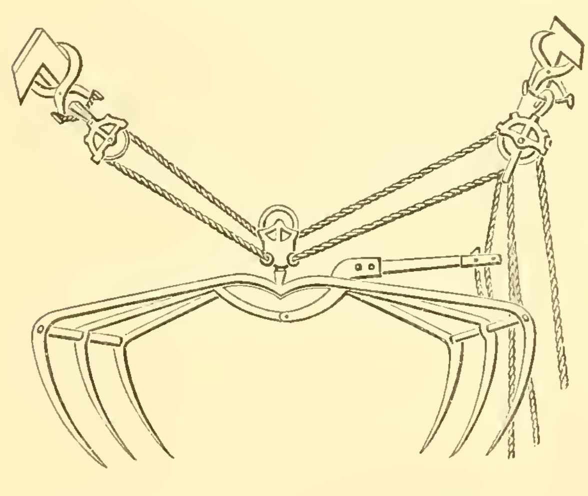


A double hay-fork is represented in Fig. 100, and another in Fig. 101, which consists of two three-pronged forks connected by a hinge. Fig. 102 shows a simple clamp for attaching this fork to a beam. It is raised and lowered by the double ropes passing over two fixed pulleys and the one on the elevator—the horse moving twice as fast as the load is raised.

For pitching hay, or any material which hangs well together, harpoon-forks work most rapidly, but they are obviously not suited for short straw.

Walker's harpoon is a straight bar of metal, appearing almost as simple as a crowbar (Fig 103). Its point is driven into the hay as far as desired, when a movement at the handle is made, which turns up the point at right angles (Fig. 104), enabling it to lift a large quantity of hay. A modification has spurs, which are thrown out on opposite sides. The combined fork and knife invented by Kniffen and Harrington is an excellent hay-knife when folded, as shown in Fig. 106, and an efficient elevator when opened, as shown in Fig. 105. At a trial in Auburn, New York, this fork discharged a load of hay weighing 2,300 pounds, over a beam, in two minutes.

101.



102.

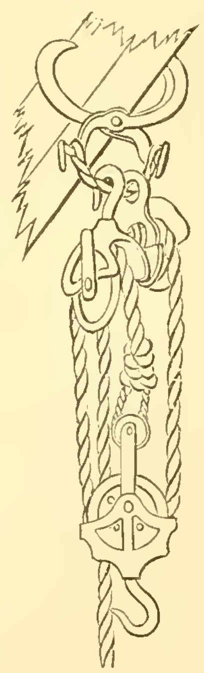


Fig. 107 represents a hay-stacker, which first elevates the hay, and then swings it around over the stack, dropping it where desired. The horizontal motion of the crane is effected as follows: Two ropes are attached to the whippletree; one, a strong one, to elevate the hay, running on the pulleys at *B*, *C*, and *D*; and the other, a smaller one, passing the swivel-pulley at *A*, on the end of the lever *B*, extending from the foot of the upright shaft. This cord then passes up and over a pulley above the weight *E*. The weight is about four pounds, and is attached to the end of the smaller cord. At the same time that the horse, in drawing, elevates the fork with its load of hay, the weight *E* is raised until it strikes the pulley, when the power of the horse becomes applied to the end of the level *B*, causing it to revolve, and swing the hay over the stack. As the horse backs, the weight drops again to the ground, taking up the slack rope from under the horse's feet, and the weight of the fork causes the arm of the derrick to revolve back over the load. The intended height for raising the hay, before swinging, is regulated by lengthening or shortening the smaller cord, as the arm will not revolve until the weight strikes the pulley under the head-block.

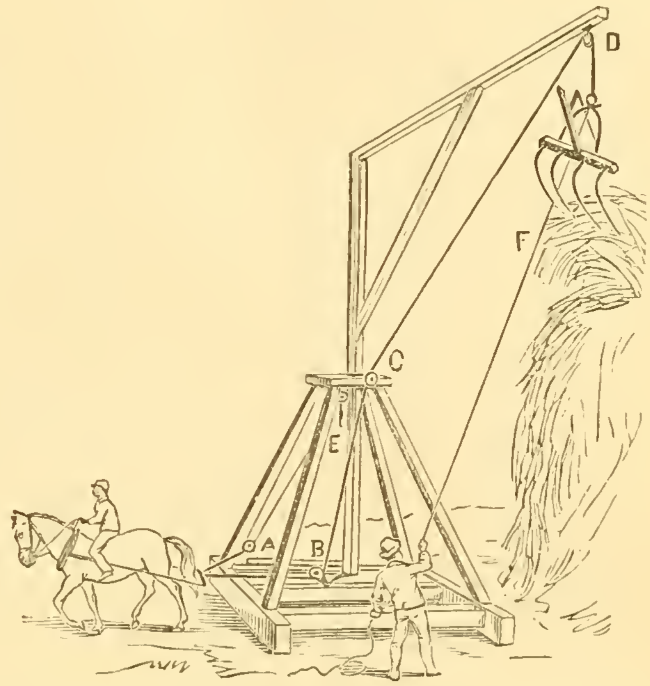
5. *Implements for preparing Crops.*

*Thrashing-Machine.*—Thrashing and cleaning machine. Thrashing and separating machine. Thrashing and winnowing machine. All the above terms are applied to the same class of implement. The operation of simply thrashing is rarely resorted to, since the additional parts necessary to perform the winnowing add but very little to the cost, while increasing vastly the utility of the machine. The term cleaning, as applied to thrashing machines, is synonymous with the term winnowing. The term separating, however, is applied to such processes as separate the grain from the straw, and all such other purifying and assorting as cannot be performed by the simplest process of winnowing. Hence processes which separate the grain into divisions of equal gravity are separating processes, while those intended simply to remove matter foreign to the grain itself are termed cleaning processes. The first and simplest processes of cleaning and separating only are performed in the thrashing

machine—the further cleaning, polishing, and separating processes being done by the miller. See Mills.

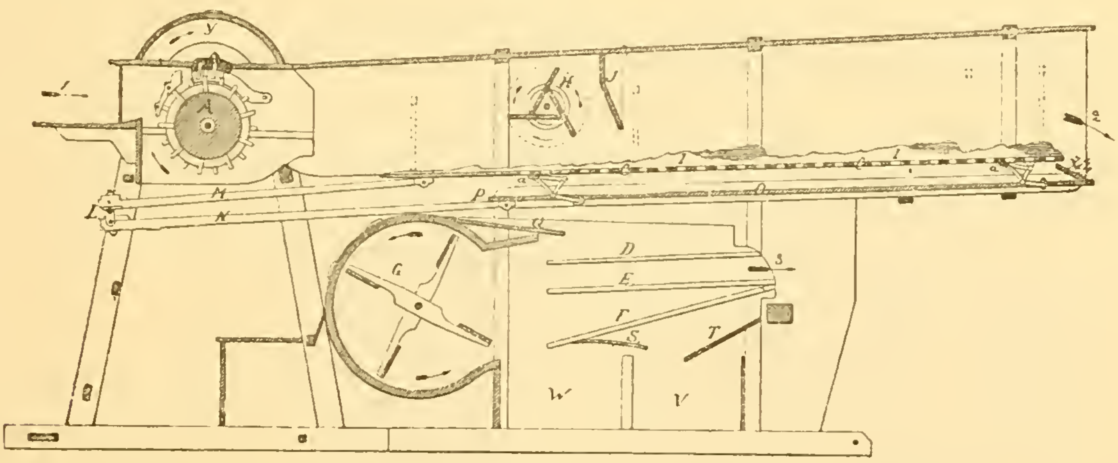
104. 103. 105. 106.

107.

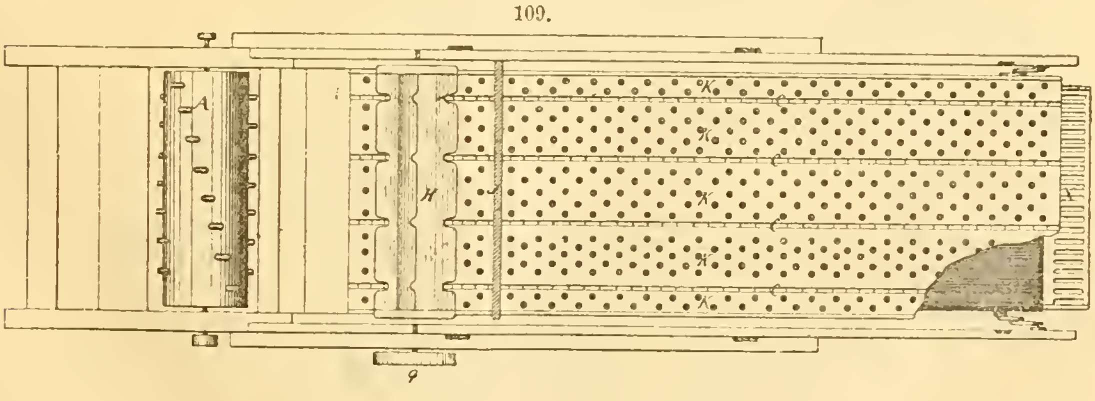



In Fig. 108 is represented a sectional view of an excellent thrashing and cleaning machine, the design of Minard Harder, of Cobleskill, New York. In this machine the grain is fed into the machine as denoted by the arrow marked 1, the thrashing operation being performed conjointly by the roller *A* and the concave; thence it passes to the separator *C*, which allows the loose grain to fall through, while the straw passes along, finding exit as denoted by the arrow 2. The grain and chaff passing through the

108.



109.

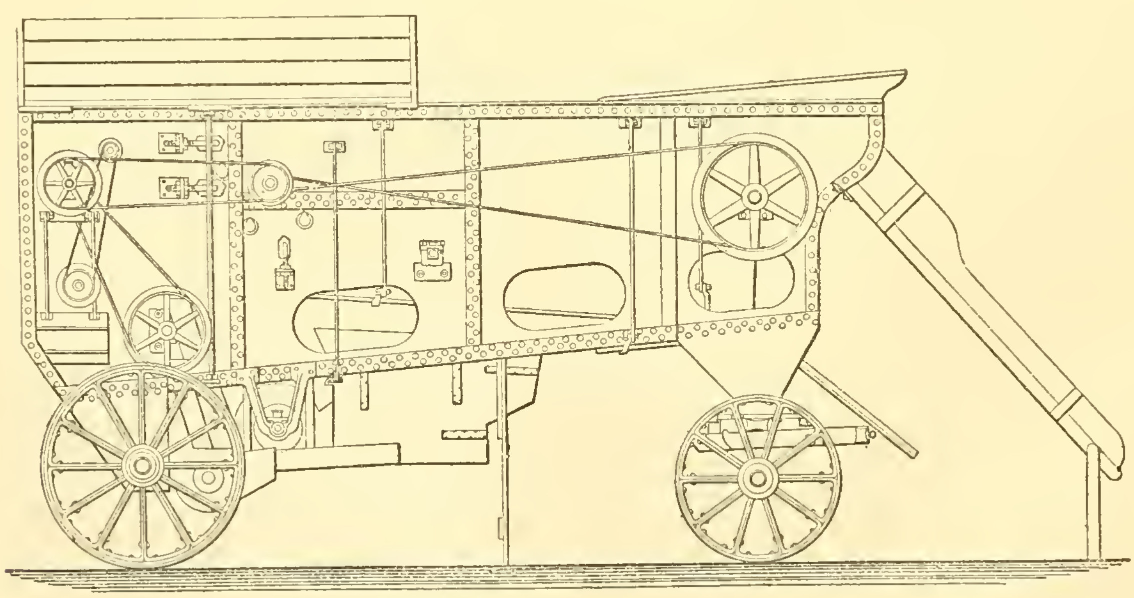


separator fall into a trough and thence to three sieves marked respectively *D*, *E*, and *F*. *G* is a revolving fan which forces a current of air between the sieves, the grain falling through while the chaff and dust are carried away with the air-current produced by the fan. The revolving cylinder *A* is pro-

vided with a series of spikes arranged spirally in rows around its circumference. The concave is a bar standing parallel with the axis of the cylinder *A*, and contains stationary spikes, and in the passage of the straw through these spikes the thrashing is performed. The spikes beat the grain-ears, loosening the grain therefrom. The rotary motion of the cylinder *A* throws the grain and straw to the separator *C*, and to maintain an even feed of the same to the separator the beater *H* is provided, consisting of a revolving shaft carrying three wings. This serves also to prevent the grain-straw from being thrown by the cylinder *A* too far forward upon the separator *C*. In the rear of the beater or feeder, and equalizer, as it may be more properly termed, is hinged a light board marked *J*, whose duty is to force the straw lightly down, and prevent its being thrown too far forward by the beater. The separating device is shown in Fig. 109, in which *K K K K K* are perforated boards between each of which are situated the blades *c*. These perforated boards and the blades are operated reciprocally, the motion of the boards being in a direction opposite to that of the blades *c*; the motions are slightly vertical as well as lateral, so that during the reciprocating movement the blades rise and fall through the separator-boards. When the motion of the blades is toward the arrow 2, in Fig. 108, the blades lift, thus carrying the straw toward that end of the machine. The blades *I* are not level upon their upper edges, but are serrated with teeth similar to saw-teeth, the front of the teeth facing the rear of the machine so as to hold the straw on the one stroke, and allow it to pass over the sloping back of the teeth during the backward motion. In addition to this, the upper edge of the blades has a wave-like form, and the highest part of one blade is opposite laterally to the lowest part of the next one, so that they impart to the straw a combined zigzag, vertical, and horizontal movement toward the arrow marked 2, affording ample disturbance to the straw to insure the falling of the grain therefrom. The double crank denoted by *L* is employed to operate the rod *M*, which is attached to the separator, and also the rod *N* attached to the trough *O*. The separator and the trough are suspended by links. By suitable construction, while a reciprocating movement is given to the separator in nearly an horizontal plane, the blades are made to receive, in addition to this horizontal movement, simultaneously with the separator, a vertical movement (up and down) at nearly right angles in relation to the separator. The grain after falling through the separator to the reciprocating trough *O* traverses by reason of the motion of the trough and its own gravity to the end *P*, and thence falls to the delivery-board *Q*. Upon the end of the board *Q* is a row of forks *f*, whose duty is to prevent foreign substances from falling in a body upon the first sieve *D*, which is termed the chaffing-sieve. The middle sieve *E* carries the operation of cleaning still further. The sieve *D* is coarsest, and has its square meshes of the same size for all kinds of grain, while the mesh of the middle sieve is varied in the size and shape of its mesh to suit the grain. For buckwheat and barley a square mesh, and for wheat, rye, and oats, a mesh longer than it is wide, are employed. The lower screen *F* has more slant than the others, in order to separate seeds and small grain. The cleaned grain falls from the sieves into the grain-spout, and the screenings into the screening-drawer at *V*, while the chaff and dust pass out with the air-current as shown by the arrow 3. The capacity of this machine, as determined by a test in Auburn, New York, in 1866, is 250 bundles of wheat-straw, producing 11 bushels of very clean wheat, thrashed in 40 minutes.

In Figs. 110 and 111 are represented an English thrashing-machine. Fig. 110 is a side elevation, showing the framing, stiffened around the edges, and at intervals in the length, by plates. It also

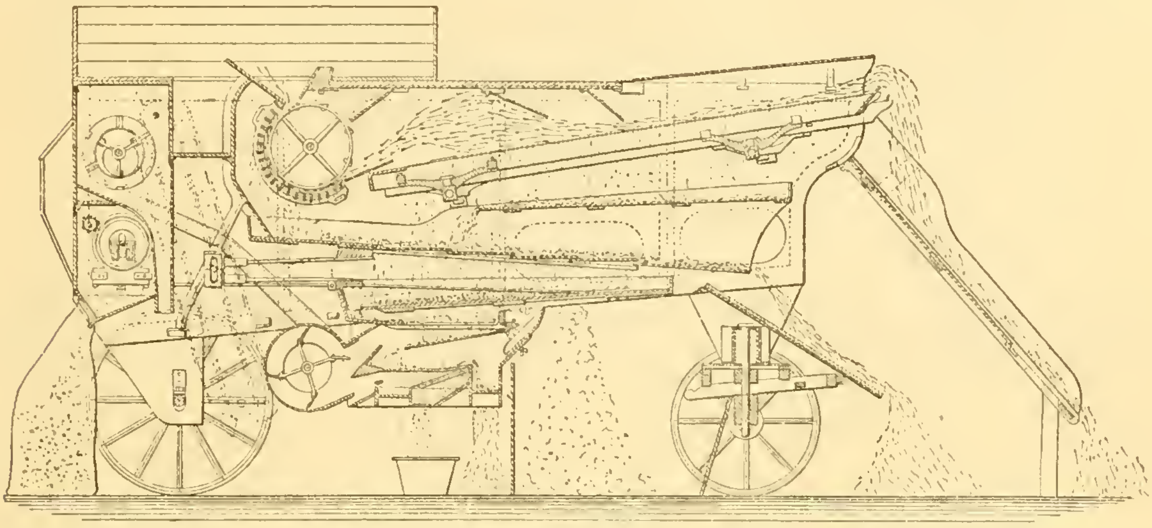
110.



shows the arrangement of the pulleys for driving the drum, shakers, fan, etc. The other view is of a longitudinal section through the centre of the machine, and shows clearly the arrangement of drum, shakers, shoes, barley-awners, and fan. The engravings explain the arrangement of the machine thoroughly, and we need not, therefore, attempt any detailed description, but confine ourselves to the special features of this machine, other than the iron framework mentioned above. The drum-spindle is of steel, and the rings placed upon it are slotted out, as shown in Fig. 111, to receive a number of iron bars, to which the beater-plates are attached, this arrangement being found preferable to introducing wood beneath the beaters. The concave at the back of the drum is entirely of wrought-iron.

The shakers consist of four boxes, the straw-platforms being arranged as shown. They are actuated by two crank-shafts, one at each end, connected with the shakers by brackets. The cranks are provided with long bearings, and a collar at each end, over which the top bearing-block overlaps, to keep out the dirt. The reciprocating dressing-shoes are hung on spring rods, as shown, and are worked by a crank-shaft similar to those for the shakers. The whole of the blast employed in the machine is taken from one fan, shown in Fig. 111, one part being taken under the riddle of the main dressing-shoe, and the other thrown upward to act on the corn as it passes from the cleaner to the screen.

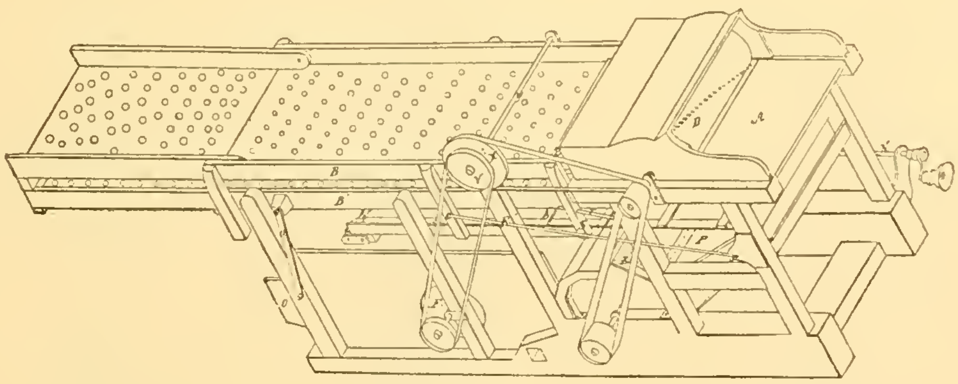
111.



The elevators are entirely within the machine, and lift the grain from the reservoir. It will be noted that the main difference between the English and American machines consists in that, in the former, revolving flails are employed instead of a spiked roller and concave. In England, however, the straw is used for thatching barns and stacks, so that it is desirable that it should leave the machine unbroken. This object is better served with the revolving flails than with the spiked rollers.

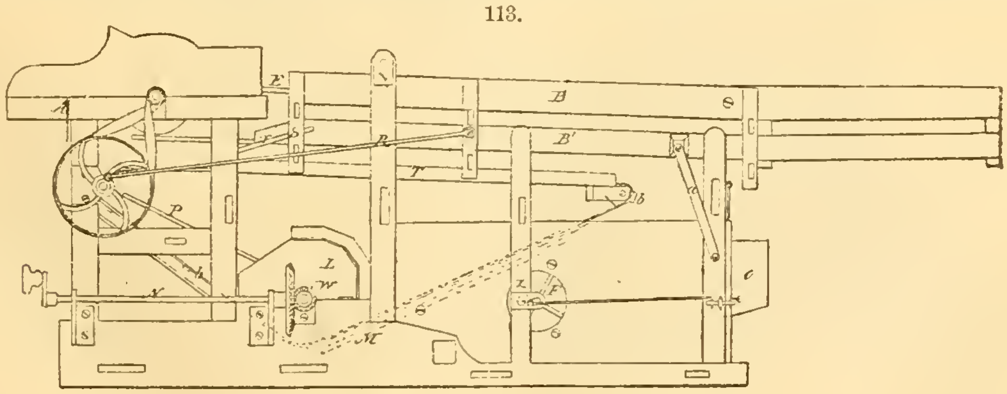
Figs. 112 to 114 represent Berdsell's improved machine for thrashing and hulling clover. The

112.



thrashing-cylinder *D* has four rows of wedge-shaped teeth set spirally on its surface, as shown in Fig. 112, which take the clover-stalks from the seed-board *A*, and carry them up as indicated by the arrow

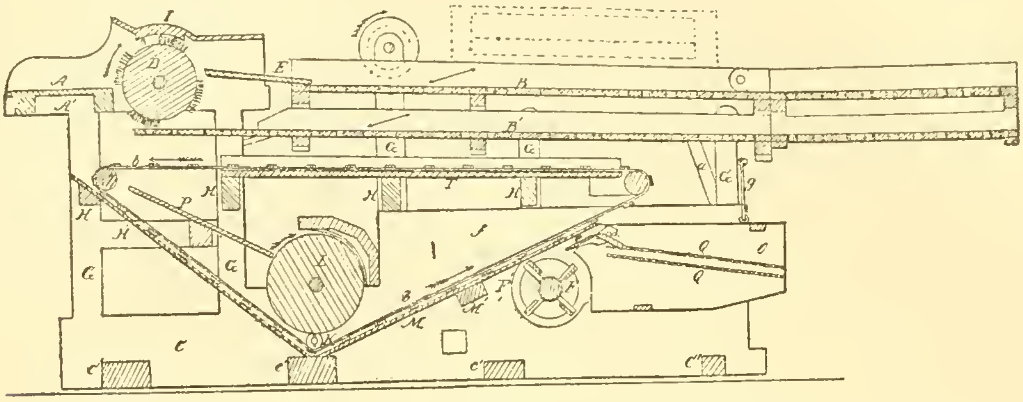
113.



under the concave *I*, which is provided with three rows of teeth. As the teeth in the concave are only half as far apart as the teeth in the cylinder, the latter are so arranged as to pass alternately through the spaces between the teeth in the concave.

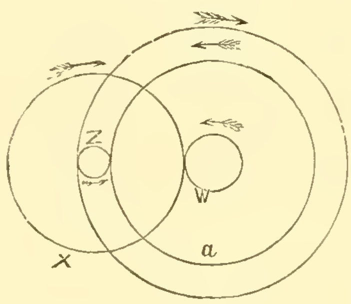
The vibrating-board *E* conducts the thrashed clover on to the upper bolt *B*, which is made of thin boards, perforated with holes one and one-eighth inch in diameter; and in the same frame is a screen

114.

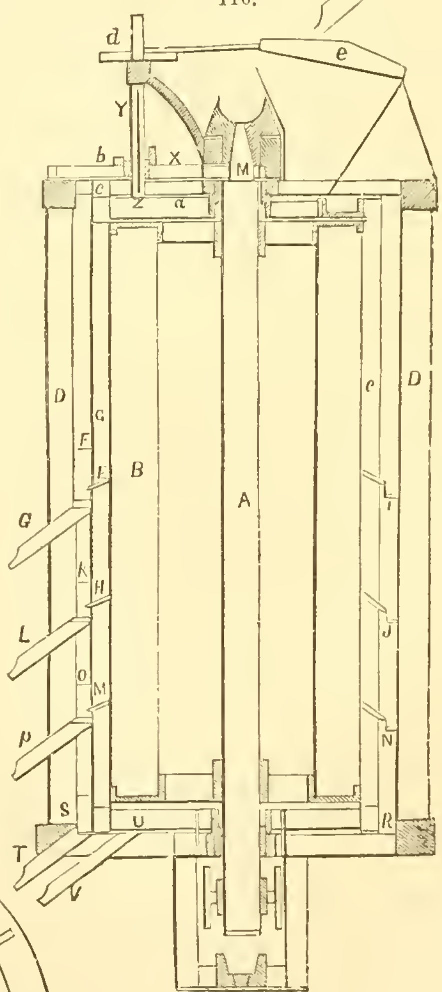


*B*′, with holes three-fourths of an inch in diameter. When the screen moves toward the thrashing-cylinder, it descends and slips forward under the straw, and rises as it moves back, carrying the straw

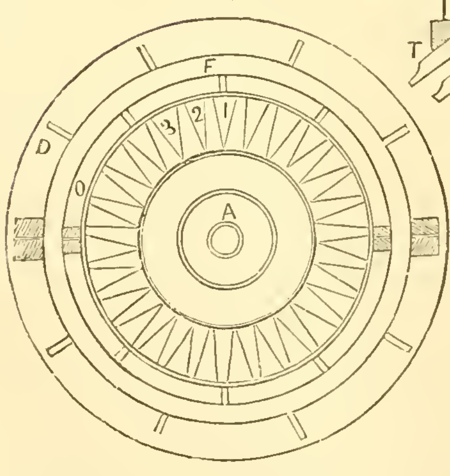
115.




116.




117.



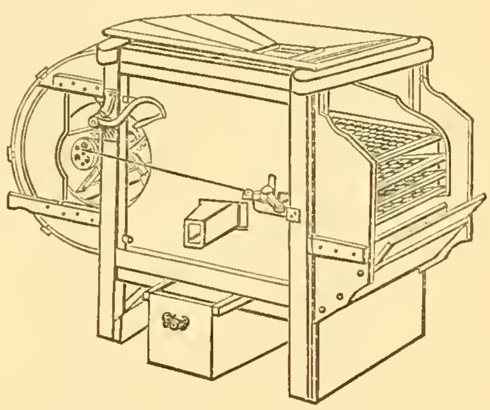

from the thrashing-cylinder, and it passes off at the end of the screen, while the bolls and seed pass through the screen on the table *T*. A belt of slats, *b b*, carries the bolls and seed off of the table

*T* on to the inclined feed-board *P*, which conducts them on to the hulling-cylinder *L*. The shaft of this cylinder may be provided with a pulley or gear to turn it and operate the machine, as the pulley 1 on this shaft is connected by belt to pulley 2 on the thrashing-cylinder. The cylinder *L* is covered with iron roughened like a rasp, and case-hardened. It is provided with a concave of iron, having a rasp-surface similar to that of the cylinder *L*, and the bolls and seed fed to the cylinder off the board *P* are carried up as indicated by the arrow, and over between the cylinder and concave which separates the bolls from the seed, both falling to the board *M'*. They are then carried by the belt of slats, *b b*, to the screens of woven wire *Q Q*, to the shoe *O*, which screens and separates the hulls from the seed, the latter passing through the screens, while the hulls pass off at the end of the screen.

The case *F''* around the fan compels the blast to pass between the end of the board *M* and the screen, so as to pass among the seed; and the blast also passes between the screens and under the lower screen, thus mingling with the falling seed. The screens *B* traverse so fast that they slip forward under the straw as they descend, and, as they rise and move back, they lift the straw and carry it back. This operation being continued, the straw passes off at the rear end of the screens.

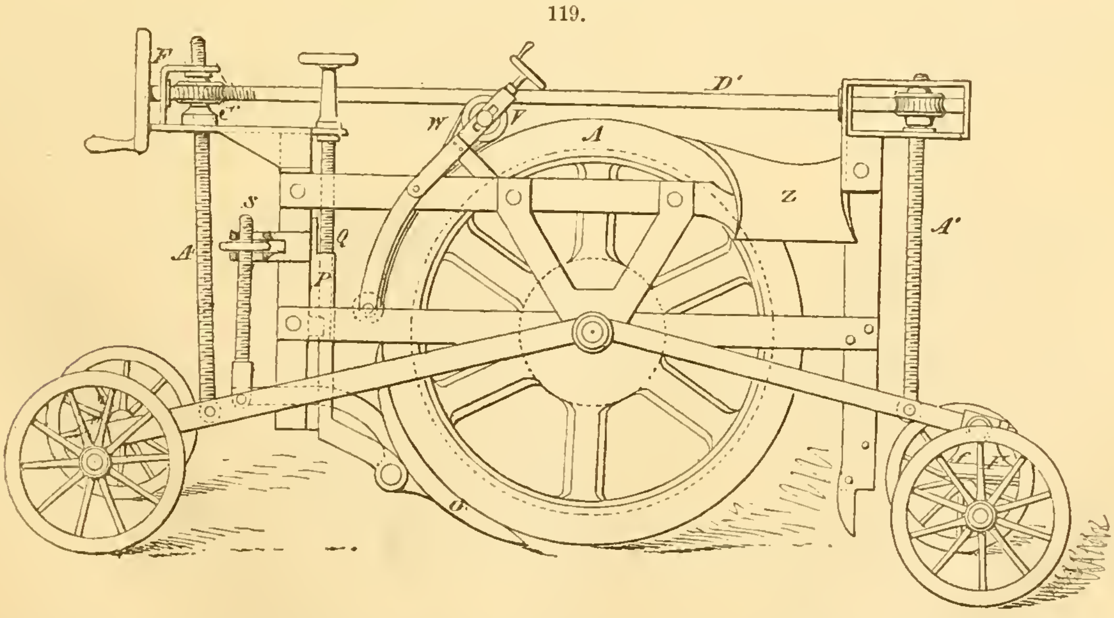
A bran-separator is illustrated in Figs. 115 to 117. Fig. 115 is a sectional view, and Fig. 117 a sectional plan, with the top parts removed, in order more plainly to show the parts represented in Fig. 116. *A* is the shaft; *B*, the cylinder; *C*, the inner revolving shell; and *D*, the outer or stationary shell. The cylinder is made by framing staves of the form and in the position represented at 1, 2, 3, etc., Fig. 117, into corresponding cast-heads; the staves thus forming the longitudinal and working surface, and which may be covered with any kind of material that will make it rough and durable. Air is let into the cylinder at the lower end, through holes around the centre, and spaces between the staves emit it to carry the flour and other stuffs through the several qualities of wire-cloth with which the inner surface of the revolving shell is covered. The cylinder is driven by a belt and pulleys, as is represented at the bottom of Fig. 116. The inner surface of the revolving shell is covered with the above-named wire-cloth. Thus, the space between the top and the beveled dividing ring *E*, Fig. 116, is covered with a quality that will let through little else but pure flour, which falls, and by the dividing ring is conducted into an endless trough *I*, attached to the inner and sheet-iron or zinc-lined surface of the stationary shell, and by the sweepers *F*, attached to the revolving shell, is brought around and discharged at the spout *G*. The space between the dividing rings *E* and *H* is covered with a quality that will discharge an inferior quality to the above, which falls, as above, into the endless trough *J*, and by the sweepers *K* is brought around and discharged at the spout *L*. The space between the dividing rings *H* and *M* is covered with a quality that will take out the fine particles of the bran, called dusting, which falls, as above, into the endless trough *N*, and by the sweepers *O* is discharged at the spout *P*. The space between the dividing ring *M* and the bottom is covered with a quality that will separate the shorts from the bran, the shorts falling to the bottom, or into the endless trough *R*, and by the sweepers *S* is discharged at the spout *T*, the bran passing down the inside of the revolving shell, and by the arms *U* of its cast-head is swept around to and discharged at the spout *V*. The revolving shell is driven by a combination of gear-wheels.

118.



*Fanning-mills* or winnowing-machines clean coffee, grain, etc., from chaff, dirt, and other light impuri-

119.

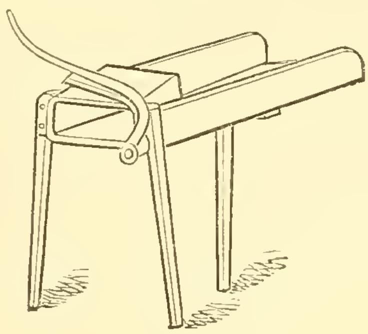



ties. The apparatus shown in Fig. 118 is designed for hand-use. Multiplying gear is placed between the crank-handle and bar shown. The sieves are vibrated by means of a crank disk-rod and bell-

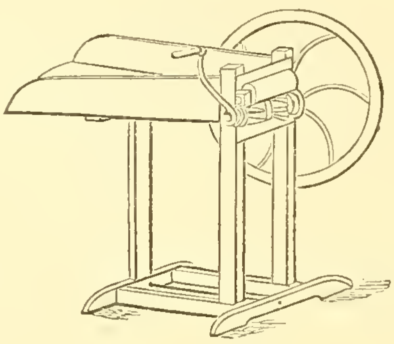
crank. The grain is fed in at the top, and passes through the sieves, the uppermost of which is coarse, while the lower ones are of varying degrees of fineness, the object being to distribute the fanning duty, by arresting the motion of the grain, so that the coarser impurities pass out between the upper and the finer ones between the lower sieves.

6. *Miscellaneous Agricultural Implements.*—Of these there is a large number variously adapted to special uses. As a representative of a very important class, we introduce Fig. 119, which is a *ditcher*, designed by ex-Governor Randolph, of New Jersey. In this machine the flange-wheel *A* cuts the ground upon each side ready for the cutter *O* to slice out the soil, which is elevated and delivered at the side of the machine at *Z*. The screw-gearing serves to regulate the depth, etc., of the trench. This machine has dug a ditch 1,000 feet long, 2 feet deep, and 5 inches wide, in one hour, the soil being heavy muck and blue clay.

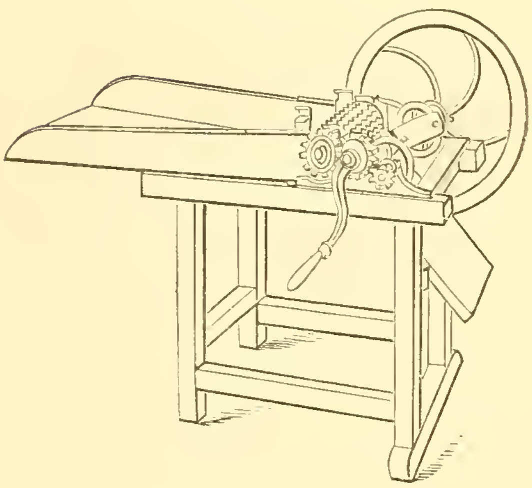
120.



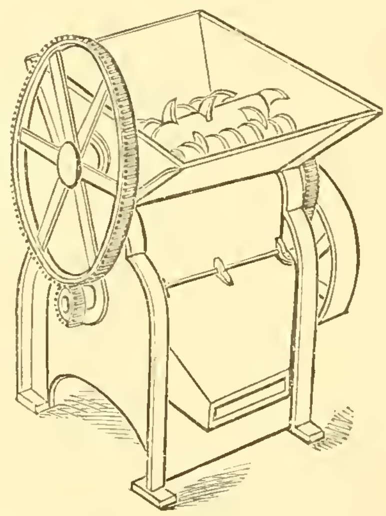
122.



121.

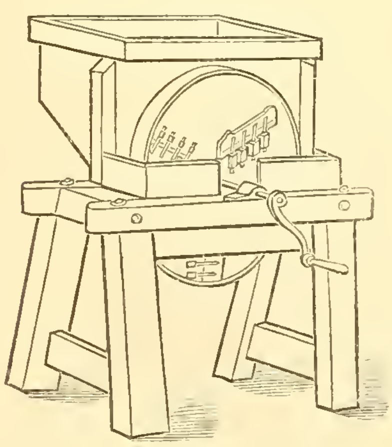


123.

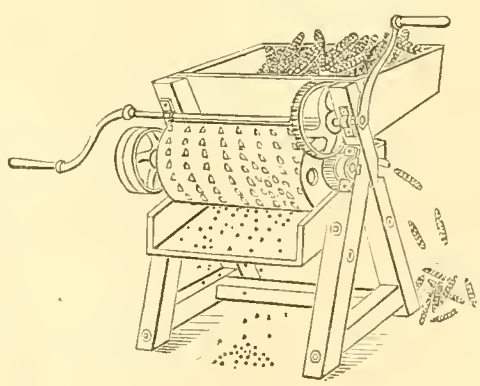


*Feed-cutters* are employed to cut feed for cattle. Fig. 120 is an apparatus having a simple lever carrying a knife. To the end of the trough is attached a stationary blade. The fodder is fed through the trough by hand between the knives. Fig. 121 shows a geared stalk and straw cutter, having self-feeding spiked rollers. It has two revolving knives and a fixed knife. The apparatus shown in Fig. 122 has spiral knives, above which is a roller composed of disks of raw-hide closely compressed upon a mandrel. Between the roller and knives the material passes. Fig. 123 represents a machine

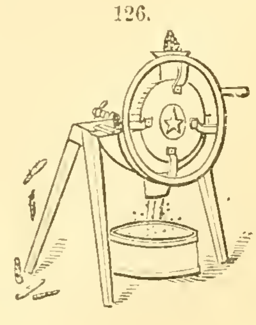
124.



125.



126.



for mixing corn and cobs for feed. It is driven by power, the operation being performed by the revolving hooked teeth. The speed should be about 600 revolutions per minute. Fig. 124 is a machine

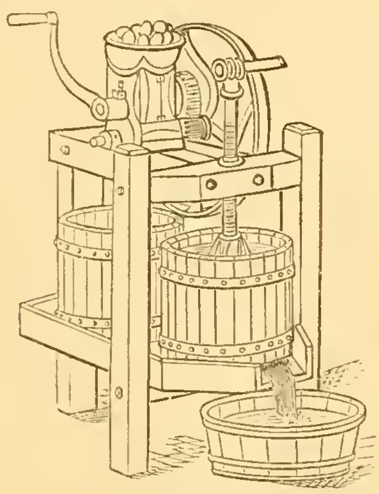
for cutting vegetables for fodder. The cutting-wheel is made of cast-iron, through which are inserted three knives similar to plane-irons; these cut the vegetables into thin slices with great rapidity, and the cross-knives operate to cut and break them into irregular pieces of convenient form and size for cattle or sheep.

*Corn-shellers* remove the grain of Indian-corn or maize from the cob. The general principle followed is that of scratching off the corn by means of short spike projections upon a cylindrical or flat surface. The operation of the apparatus shown in Fig. 125 is evident. In the machine shown in Fig. 126 the spiked teeth are arranged radially upon a rotating disk, the cobs being fed singly, and presented lengthwise to the face of the disk.

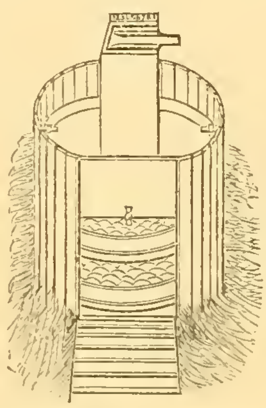
*Cider-Mills.*—These usually consist of a grinding-mill and a press, for crushing apples and expressing the juice. The apples are placed in the hopper, as shown, and the pulp, after grinding, is placed in the press (Fig. 127).

*Incubators.*—The essential elements involved in hatching eggs by artificial means are that the eggs shall be kept for 21 days at a temperature of about 102° Fahr., and that in no case shall that temperature fall below 100° or rise above 106°, while the eggs should be carefully turned over once in every 24 hours.

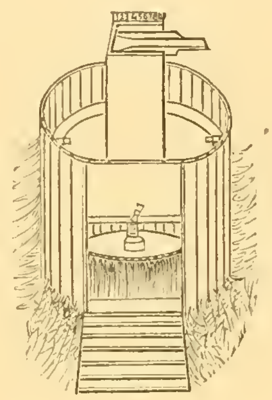
127.



128.



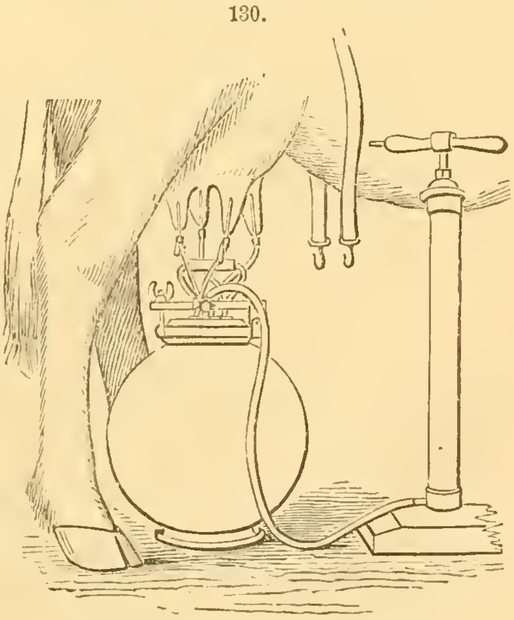
129.



In Fig. 128 is shown a simple form of this apparatus known as Corbett's incubator, which consists of a cylindrical wooden box, in which are placed two sieves containing the eggs. During the process of hatching, the box is buried to its upper edge in horse-manure, which must, however, be the product of grain-fed (not grass-fed) horses, and must not be over two months old. The ventilator shown at the top is opened to reduce the temperature as desired. After the eggs are hatched the chicks are removed to what is termed the "artificial mother," shown in Fig. 129. This is a box exactly the same as the incubator, but provided with an horizontal disk, covered on the underside with a piece of sheep-skin from a long-wool sheep, and arranged to be moved up and down by a screw. The manure is heaped partly around the box, to provide the needed warmth; the door is let down for a pathway in and out for the chicks (see Fig. 129), and in this they are placed as soon as ready to be removed from the incubator. After having been fed a few times, the chicks will learn to come out from beneath the wool to feed when the platform is tapped.

*Cow-Milker.*—An apparatus for milking cows is shown in Fig. 130. It consists of a glass receiver, having a cover which may be closed air-tight. Through this cover extend four rubber tubes, which terminate in metal tubes attached to the teats. Air is exhausted from the receiver by the pump shown, and the milk thus drawn down. The device may be suspended by the hooks on a strap over the cow's back. J. R.

130.



AIR-COMPRESSORS. Machines for compressing air, which is afterward to be used in suitable engines as a motor, or through its expansion as a means of reducing the temperature of adjacent bodies, or as a blast for forges, etc. The machines performing the last-mentioned duty are known as blowing engines and blowers. The name "blower" is more commonly applied to rotary machines, either force, blast, or fan, and "blowing engine" to piston apparatus. The former, having a wide range of uses, are separately treated under BLOWERS. For mechanical applications of compressed air, see BRAKES, CAISSONS, DIVING, FOUNDATIONS, HAMMER, LOCOMOTIVE, RAILROAD, REFRIGERATING MACHINERY, and TELEGRAPH. For theoretical considerations, see STEAM.

Apparatus for compressing air includes, first, a motor; second, a machine wherein the air is compressed. Compressors may be classified as follows: 1. With regard to air-pressure generated. *Low-pressure compressors* are those in which air is compressed to a

pressure not exceeding 2 absolute atmospheres—that is to say, to less than one effective atmosphere. *Medium-pressure compressors* are those in which the pressure attained is compressed between 2 and 4 absolute atmospheres, or between 1 and 3 effective atmospheres. *High-pressure compressors* are those in which the air is compressed to between 4 and 8 absolute atmospheres—that is to say, below 2 effective atmospheres. *Very high-pressure compressors* are those in which the air is compressed to pressures above 8 absolute atmospheres.

2. With regard to volume furnished at a given pressure, each one of the foregoing classes may be divided into *low-duty* and *high-duty* machines. Each of these subdivisions may be again divided into *piston-compressors*, the primitive type of which is the blast-machine of blast-furnaces, in which the air contained in a cylinder is brought to the desired pressure by means of a piston which gradually decreases the volume of the cylinder to that which corresponds to the pressure desired ; and *compressors without pistons*, the primitive type of which is the *trompe* or water-bellows of Catalan forges, and which includes all other machines not coming under the piston-compressor class.

In piston-compressors the piston may act on the air either directly or by the intermediary of water, which serves as packing. Hydraulic piston-compressors, as the last-mentioned class may be termed, may be again divided in accordance with the means used for cooling the air and the cylinder. As each class above mentioned will be considered in turn, for the convenience of the reader the various groupings are recapitulated as follows in their proper connection:

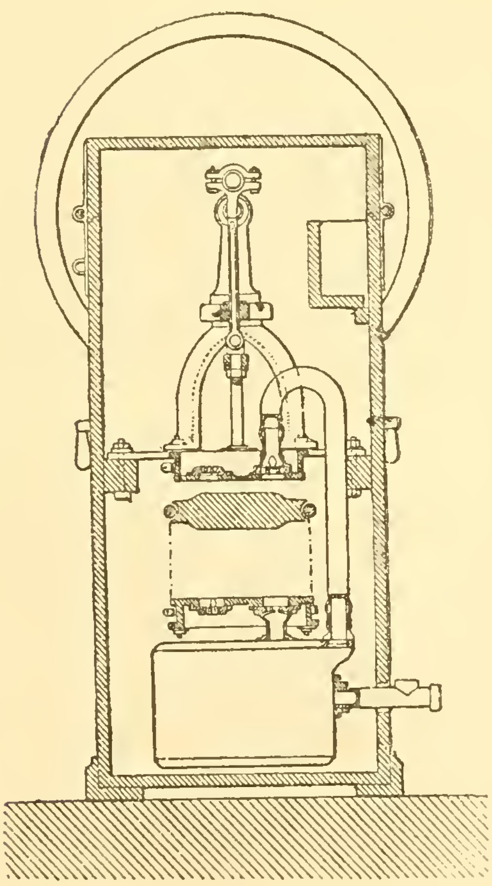
I. Low-Pressure Compressors.

A. *Low-duty Machines.*
B. *High-duty Machines.*
  1. Exhausting and compressing apparatus for sugar-works.
  2. Blowing-engines for blast-furnaces, which include (*a*) walking-beam engines, (*b*) horizontal engines, (*c*) vertical engines.
  3. Compressing and exhausting machines for pneumatic telegraphs.
C. *Compressors without Pistons*, which include—
  1. Water-machines. 2. Steam-machines.

II. Medium-Pressure Compressors.

A. *Low-duty Machines.*
  1. Forcing-pumps, for diving-apparatus.
  2. Compressors for compressed-air wells.
  3. Compressors for pneumatic foundations and caissons.
B. *High-duty Machines.*
  1. Blast-engines for Bessemer converters.

131.



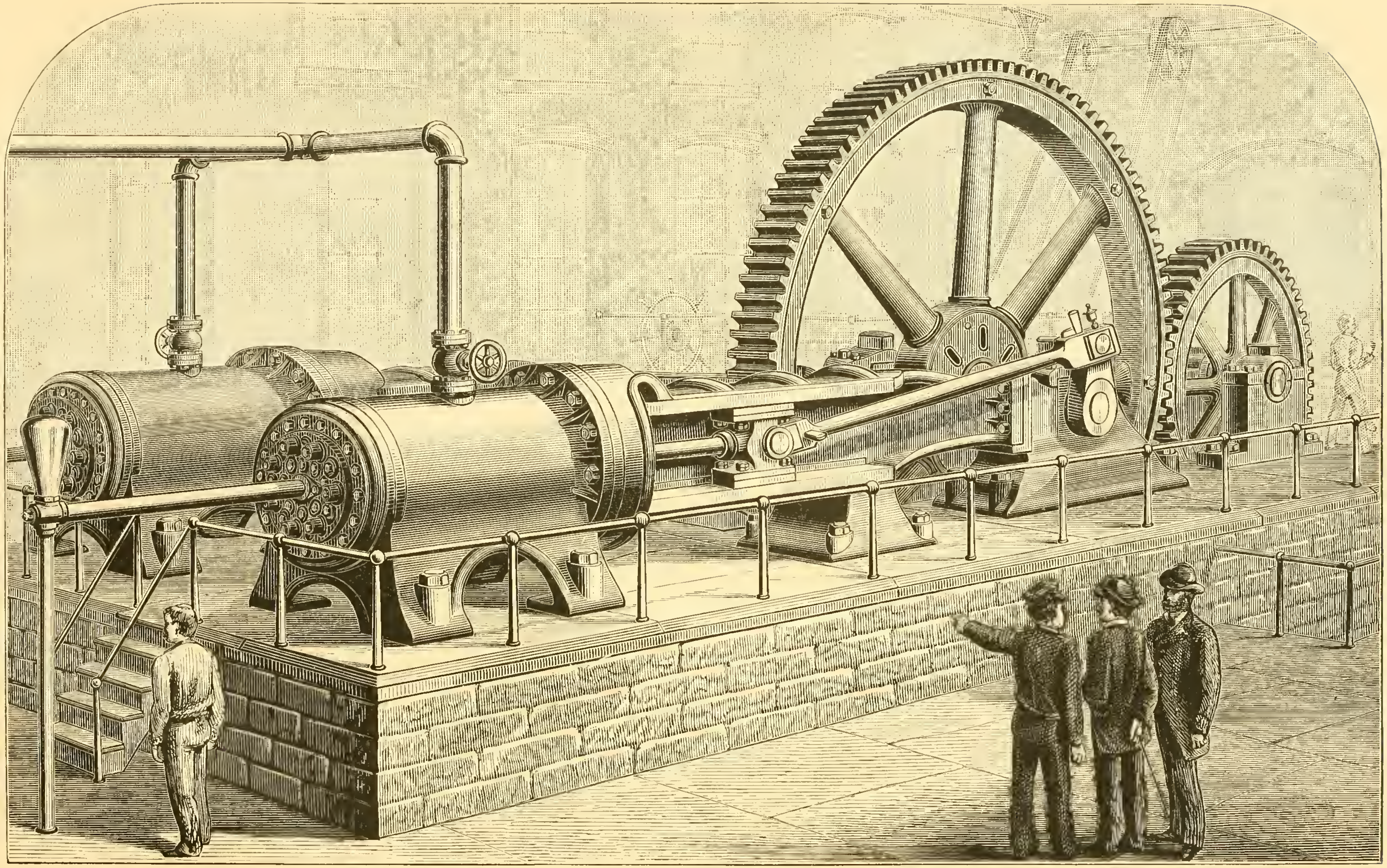
III. High-Pressure Compressors.

A. *Low-duty Machines.*
  1. Piston-compressors acting directly on the air to be compressed.
  2. Hydraulic piston-compressors.
B. *High-duty Machines.*
  1. Compressors in which there is no refrigeration.
  2. Compressors in which the refrigeratory apparatus is purely exterior, and is a water-envelope, or a jacket in which there is water in circulation.
  3. Compressors in which refrigeration is effected by water maintained on the piston.
  4. Compressors wherein refrigeration is received by water introduced at the periphery of the compressing piston.
  5. Compressors wherein refrigeration is effected by injection of water in the compressory cylinder.
  6. Compressors wherein refrigeration is effected by injection of water in spray in the compressing cylinder, and by circulation of water in a jacket about the same, and also within the piston.
  7. Hydraulic piston-compressors.
  8. Impact compressors.

IV. Very High-Pressure Compressors.

A. *Low-duty Machines.*
  1. Compressors having pistons acting directly on the air to be compressed.
  2. Hydraulic piston-compressors.
B. *High-duty machines* subdivided in the same manner.

I. Low-Pressure Compressors. A. *Low-duty Apparatus.*—This class includes hand and forge bellows; also, forcing-pumps for supplying air to respiratory apparatus used by firemen, etc. The Fayal pump, Fig. 131, consists of a leather bellows, fixed between heads, in which are inlet and delivery valves. In the centre of the bellows is a piston of wood, connected by a split connecting-rod with the crank-

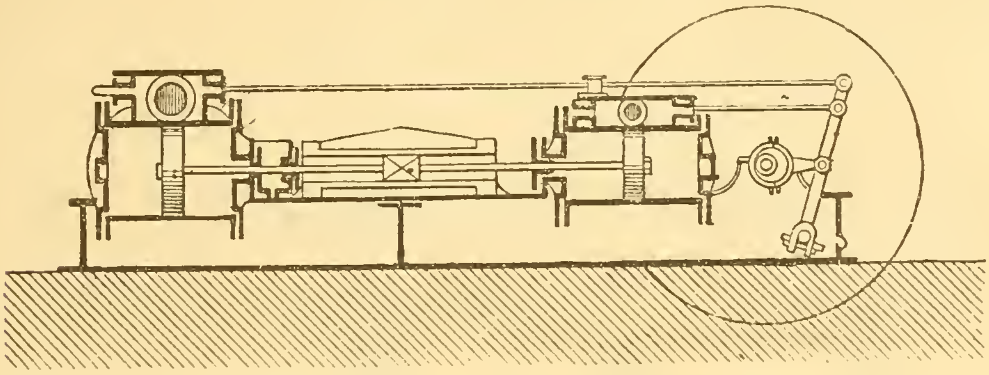


RAND AIR-COMPRESSOR.

shaft and wheel. The air is driven into a sheet-iron reservoir in the lower portion of the machine, which communicates with the delivery-valve, and by a lateral tube with the air-conduit. This apparatus furnishes air under pressure of from 11.7 to 15.6 inches of water, and this excess of pressure of from .04 to .03 atmosphere is sufficient to supply fresh air to five or six miners with their lamps at a distance of some 300 feet from the compressor.

B. *High-duty Apparatus.* 1. *Machines for Sugar-Works.*—Fig. 132 represents the blowing and exhausting machine used in the large German sugar-works for injecting carbonic acid into the defecating apparatus. The air-cylinder is in line with the steam-cylinder, the piston-rods being

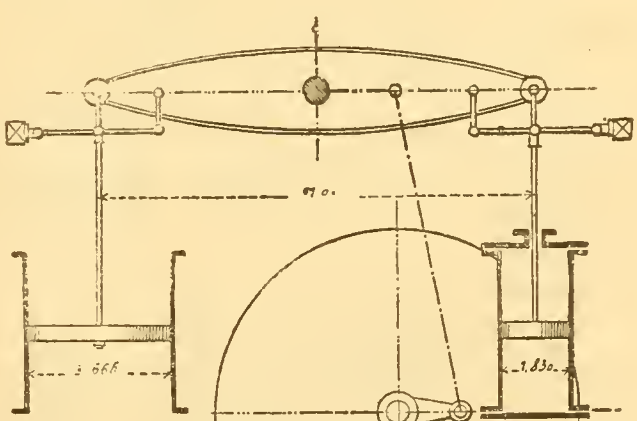
132.



connected and guided as shown. The diameter of the air-piston varies according to the power of the machine from 17.5 to 31.2 inches, the stroke generally being equal to the diameter. The revolutions vary from 35 to 60 per minute. The valve-mechanism is clearly shown in the engraving.

2. *Blast-Furnace Blowing-Engines.*—(*a*) Walking-beam Machines. Fig. 133 shows the disposition of the machine used at Ebbw Vale, Wales. This engine, owing to its size, is probably the most powerful of its class extant. The dimensions are as follows: Motor, diameter of steam-piston, 71.5 inches; stroke, 142.7 inches; length of walking-beam, 35 feet 7 inches; fly-wheel, diameter, 30 feet 7 inches; weight, 85 tons; air-cylinder, diameter of piston, 142.7 inches; area of same, 112 square feet 86 square inches; stroke, 142.7 inches; volume of cylinder, 1,358 cubic feet 818 cubic inches; revolutions per minute, 16; velocity of piston per second, 6 feet 4 inches; theoretic volume generated per minute, 43,496 cubic feet; absolute pressure of blast, 1.3 atmosphere; volume of air theoretically furnished at this pressure, 33,458 cubic feet. (*b*) Horizontal Machines. Fig. 134 represents the blowing-engine at Georgs-Marien Hütte, near Osnabrück. The steam-piston has two rods, one attached to the connecting-rod of the crank-shaft and fly-wheel, the other communicating with the air-pump piston. The principal dimensions, etc., are as follows: Absolute air-pressure, 1.33 atmosphere; volume of air furnished at this pressure, 15,421 cubic feet. Motor: Diameter of steam-piston, 4 feet 4 inches; stroke, 85 inches, cut-off at $\frac{2}{3}$ stroke. Diameter of fly-wheel, 30 feet 4 inches. Weight, 28 tons. Normal steam pressure, 4.5 atmospheres. Air-cylinder: Diameter of piston, 9 feet; stroke, 85 inches; useful volume of cylinder, 487 cubic feet; revolutions per minute, 21; theoretic volume generated per minute, 20,516 cubic feet. As will be seen from Fig. 135, the air-valves are disposed on the cylinder-heads. The inlet-valves, seven in number, are placed in three vertical lines in the upper half of the heads, and are of iron, with leather packing. Their mode of support by articulated rods is clearly shown. The total opening is .19 the piston-surface. The delivery-valves, 16 in number, are placed in six vertical lines, and are formed of leaves of rubber fixed at one side. Their total opening is .156 that of the piston-surface. The piston is hollowed. (*c*) Vertical Blowing-Engines. Fig. 136 represents a type of compressor employed in many localities in Pennsylvania. The inlet-valves are placed in the extremities of the cylinders, and are provided with springs so as to insure their rapid closing. The delivery-valves are of leather. The cylinder is surrounded by an annular chamber. The dimensions, etc., are as follows: Absolute air-pressure, 1.3 atmosphere. Volume of air at the pressure, 11,804 cubic feet. Motor: Diameter of steam-piston, 43 inches; stroke, 47.1 inches; two fly-wheels of 20 feet 4 inches diameter. Air-cylinder: Diameter of piston, 83 inches; stroke, 46.8 inches; useful volume of cylinder, 151 cubic feet; revolutions per minute, 50; volume generated per minute, 15,345 cubic feet.

133.



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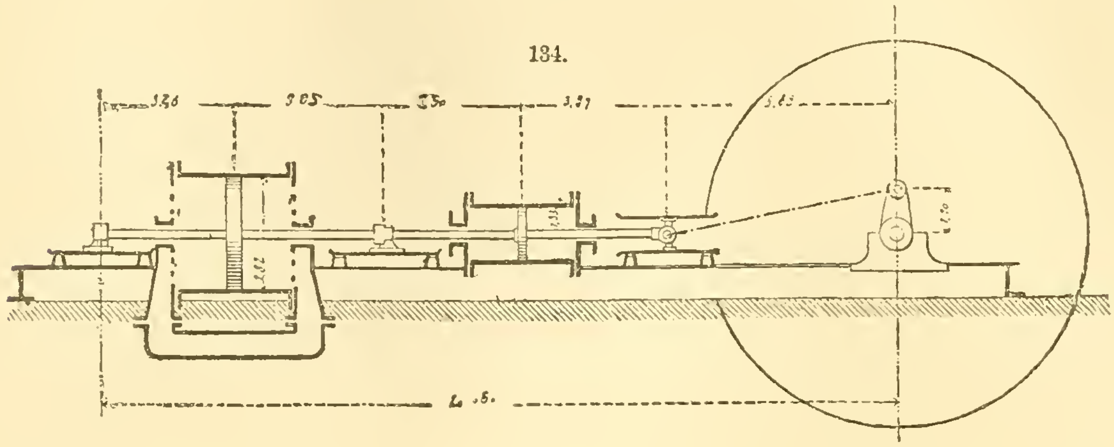
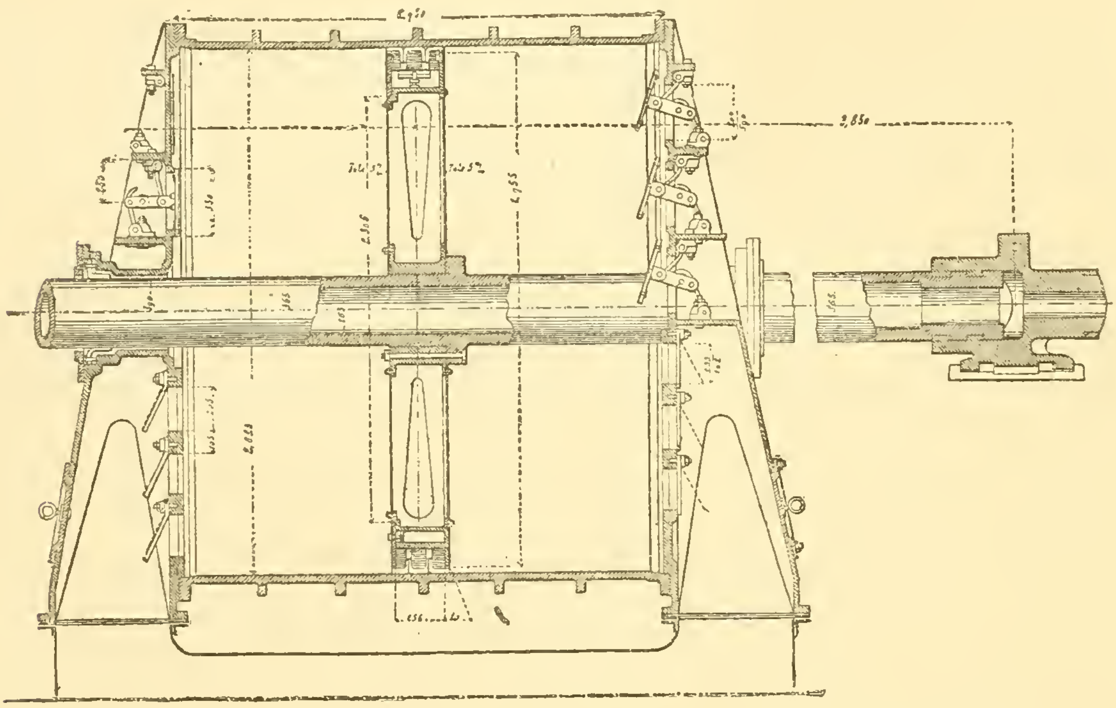


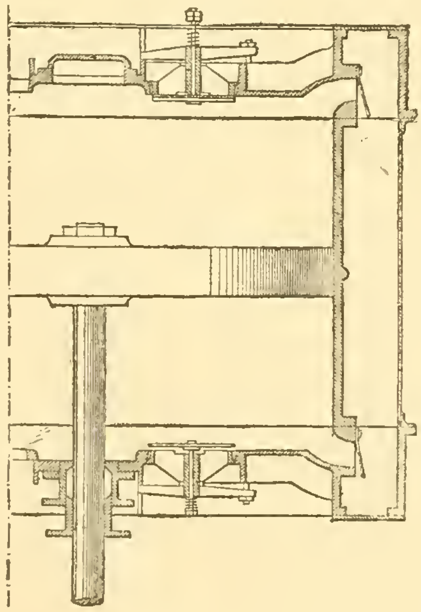
3. *Compressors for Pneumatic Telegraphs.*—These machines are used in large cities for producing the pressure or vacuum for impelling packets through underground systems of pneumatic tubes (see

135.

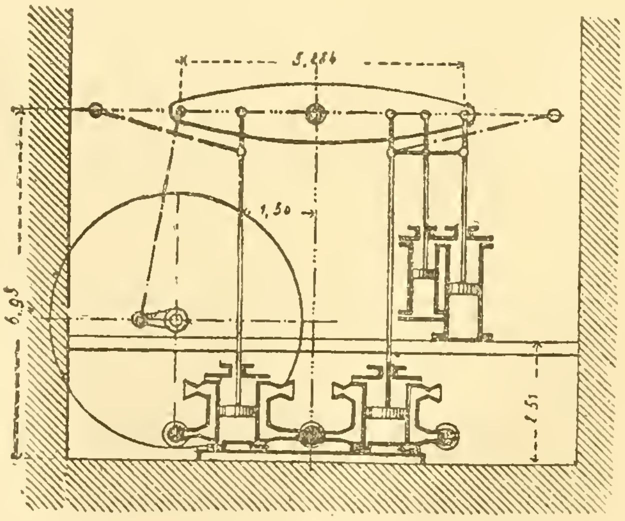


*Pneumatic Telegraphy*, in TELEGRAPH). Fig. 137 represents the machine used in the Post-Office, London, England. The walking-beam is connected with two compressing cylinders, also to steam-cylin-

136.



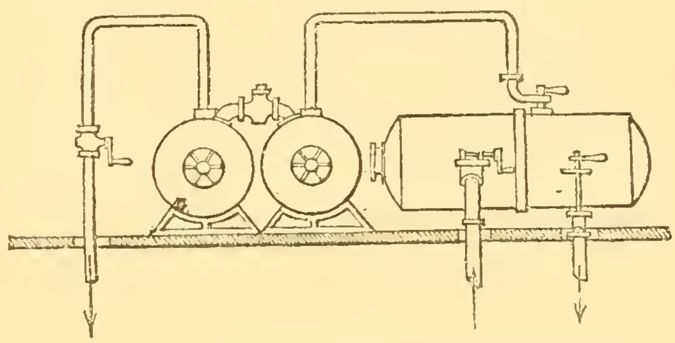
137.



ders built on the compound system, and to the fly-wheel. The absolute pressure of the compressed air is 1.7 atmosphere, and the corresponding volume of air furnished is 588 cubic feet when cylinders are single-acting; when double-acting, twice this total. The dimensions are as follows: Motor: Diameter of small piston, 16.7 inches; large piston, 24.9 inches; stroke of small piston, 48.7 inches; of large piston, 65.1 inches. Cut-off at $\frac{3}{8}$ stroke; condensing; steam-pressure, 75 lbs. Air-cylinders: Diameter of air-piston, 34.7 inches; stroke, 35.5 inches; useful volume of cylinder, 20 cubic feet 22 cubic inches; revolutions per minute, 25; volume generated per minute, one cylinder, 998 cubic feet; two cylinders, 1,996 cubic feet. The cylinders are made as shown in Fig. 137, so as to be both exhausting and compressing, or either exhausting or compressing. To this end the valves are placed in chambers on each side of the cylinder, as shown. The inlet-valves are on the left, the delivery-valves on the right. The two upper ones communicate with the atmosphere; the lower pair communicate, one with the receiver to be exhausted, the other with the compressed-air reservoir. It will readily be seen how, by suitable adjustment of these valves, the apparatus may be made to act in the different ways above described. The total valve openings aggregate air-area .0087 that of the piston-surface.

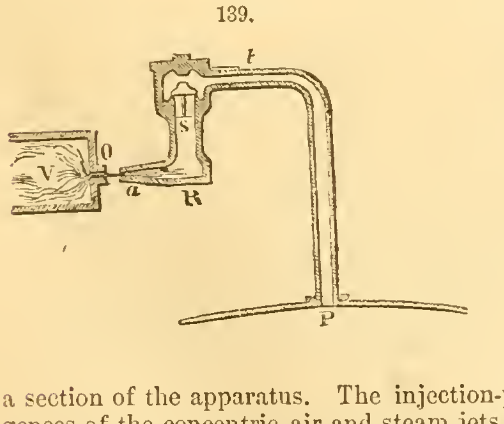
C. *Compressors without Pistons.* 1. *Water-Apparatus.*—Of this variety they are two types, that in which the compression is produced only by the progressive reduction of the volume occupied by the air in a reservoir in which water is admitted; and that in which the compression is produced by the entrainment of the air by means of a liquid vein escaping under a given pressure. The first may be termed: (1.) Simple Displacement Apparatus. Machines of this description are used in some of the pneumatic-dispatch stations of Paris. An example is given in Fig. 138. The machine consists of a water-reservoir 5 feet 2 inches in diameter, 12 feet 2 inches in length, and 64.7 cubic feet in capacity, and two air-chambers, 208 cubic feet volume. One tube connects the reservoir with the city water-mains, another serves for emptying the reservoir, and a third on the upper portion of the latter communicates with the air-chambers. The air-chambers are connected as shown, and from one a tube leads directly to the pneumatic conduit. If the three receptacles be filled with air, and placed in communication with one another, but shut off from the pneumatic pipe, water entering the reservoir at a pressure of about 35 feet drives out the air, and compresses it in the two chambers. When the reservoir is filled, the air is reduced from a volume of 663 cubic feet to one of 416 cubic feet, and the pressure amounts to 1.59 absolute atmosphere. (2.) Entrainment Apparatus. To this class belongs the well-known water-bellows or *trompe* of the Catalan forges. An improved device on the same principle has been invented by M. Romilly, and is illustrated in Fig. 139. This apparatus is formed of a conical tube *a*, having a valve *S*, which prevents the air escaping from the reservoir to which the tube is attached. Water is led in the compressing reservoir through an ajutage *O*, in the form of a liquid vein at a given pressure which entrains air with it, and so effects compression of the latter in the reservoir *V*. The reservoir is 282.4 cubic feet in capacity, and M. Romilly has determined that with water at 35 feet pressure a quantity of air can be introduced equal to .465 of the volume of the water employed raising the air-pressure to 1.6 atmosphere.

138.

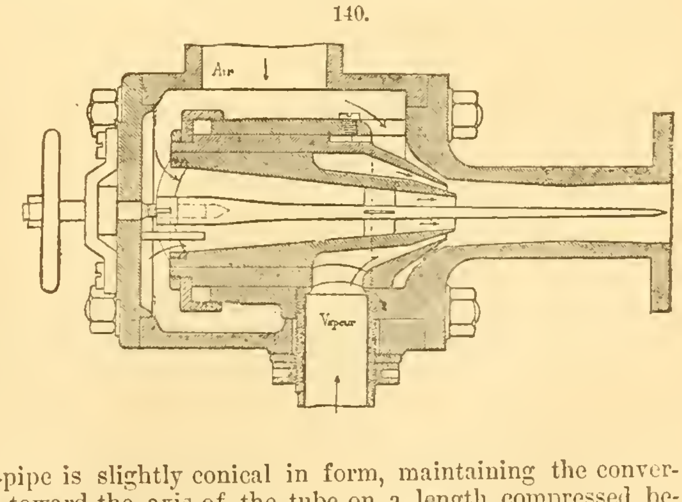


2. *Steam Apparatus. Injectors.* (See also same general heading.)—Mr. Siemens has investigated the application of the steam-injector to the propulsion of gases, and he has constructed an injector which, with steam at 45 lbs. pressure, produces a vacuum of 23.7 inches of mercury. Fig. 140 is

139.



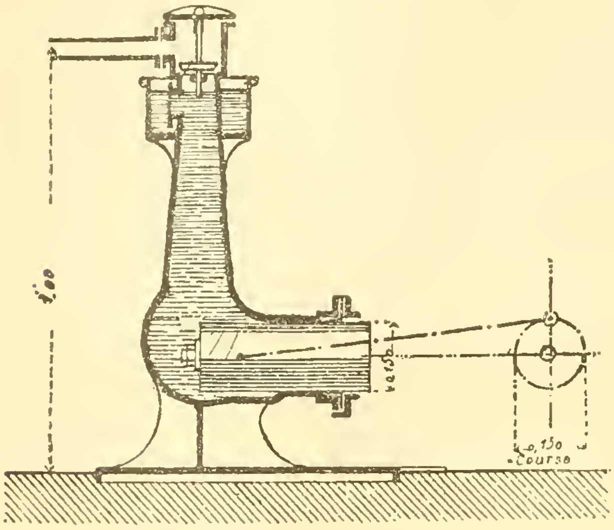

140.




a section of the apparatus. The injection-pipe is slightly conical in form, maintaining the convergences of the concentric air and steam jets toward the axis of the tube on a length compressed between twelve and twenty times the breadth of the annular air-induction aperture. The object of this convergence is to secure complete mingling of steam and air. Mr. Siemens has applied this apparatus to the production of a vacuum in 21,369 feet of pneumatic-dispatch tubes in London. Three injectors

maintained in pipes of the above length and 2.9 inches in diameter a vacuum of 9.8 inches of mercury, with steam at a pressure of 29 lbs. per square inch, and a consumption of coal of about 56 lbs. per hour. The same apparatus has been used for blast in the Siemens furnace and in sugar-works. It cannot be practically employed as a rule to effect compressions over 25.5 inches of mercury.

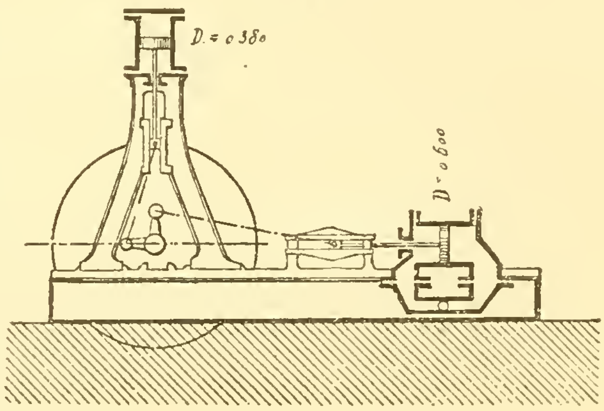
141.



3. Apparatus has been produced wherein compressed air itself has entrained the surrounding atmosphere. Experiment on this subject has not resulted in the invention of any practicable machine based thereon.

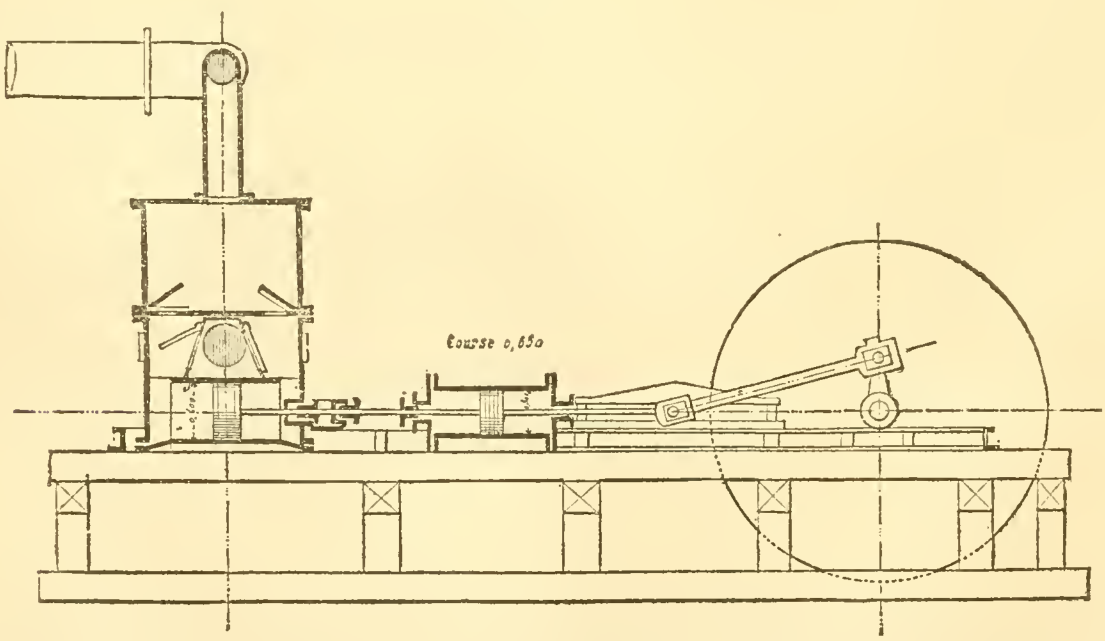
II. Medium-Pressure Compressors. A. *Low-duty Apparatus.*—1. Fig. 141 represents a compressor of the Sommeiller type designed for low duty. The piston-plunger moves in an horizontal pump-body, while the valves are placed in a vertical chamber connecting with the pump-cylinder. This column is filled with water, so that when the piston is at the end of its stroke the water covers the valve above. As at each impulsion a portion of the water is entrained by the compressed air, there is placed around the chamber a water-jacket into which a stream of water constantly enters, the liquid passing through the valve into the compressor at each aspiration. The dimensions, etc., are as follows: Absolute pressure of air, .5 atmosphere; volume of air furnished per minute, 278 cubic feet. Motor of any type: Compressor single-acting; diameter of compressing piston, 5.8 inches; stroke, same; useful volume of cylinder, 91 cubic feet; revolutions per minute, 15; theoretic volume generated by the piston at this velocity, 1,403 cubic feet.

142.



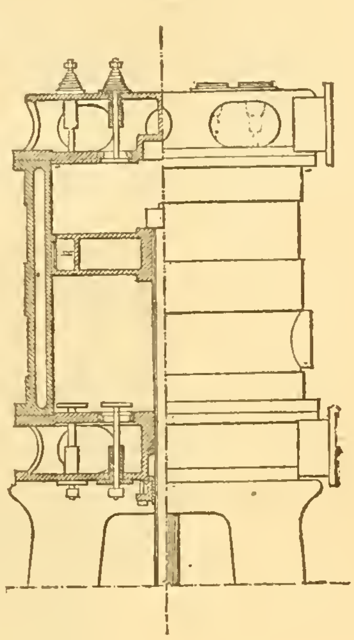

2. *Compressors for supplying Air under Pressure in Wells.*—Fig. 142 is a double-acting compressor used in sinking wells near Liége, Belgium. It is driven by a vertical engine, as shown. The aspiration-valves are fixed on the upper half of each head of the air-cylinder and open directly into the atmosphere. The compressing valves open into a chamber communicating with the lower section of each cylinder-head. This chamber is connected by a tube with the well. The following are the dimensions, etc.: Absolute air-pressure, 3 atmospheres; volume of air furnished at this pressure, 12 cubic feet. Motor: Diameter of piston, 14.9 inches; stroke, 27.5 inches; normal steam-pressure, 52.5 lbs. Air-cylinder: Diameter of piston, 23.6 inches; stroke, same; useful volume of cylinder, 6 cubic feet; revolutions per minute, 30; theoretic volume generated per minute, 35.5 cubic feet.

143.



3. *Compressors for Bridge-Foundations.*—These are mainly employed for forcing air into bridge-caissons. The disposition of the Cail compressor used at Kehl Bridge is the plan for Fig. 143. The rods of the cylinders are connected. The compressing cylinder is at the base of an iron box, so that the intermediate space between its outer periphery and the box may be filled with water. In this box also are the aspiration and compression valves. The dimensions, etc., are as follows: Absolute air-pressure, 3.5 atmospheres; volume furnished at this pressure, 60 cubic feet. Motor: Diameter of piston, 12.5 inches; stroke, 23.6 inches; fly-wheel, 6.5 feet in diameter; steam-pressure, 75 lbs. Compression cylinder: Diameter of piston, 15.7 inches; stroke, 23.6 inches; useful volume of cylinder, 4,561 cubic inches; revolutions per minute, 40; theoretic volume generated per minute, 213 cubic feet.

144.

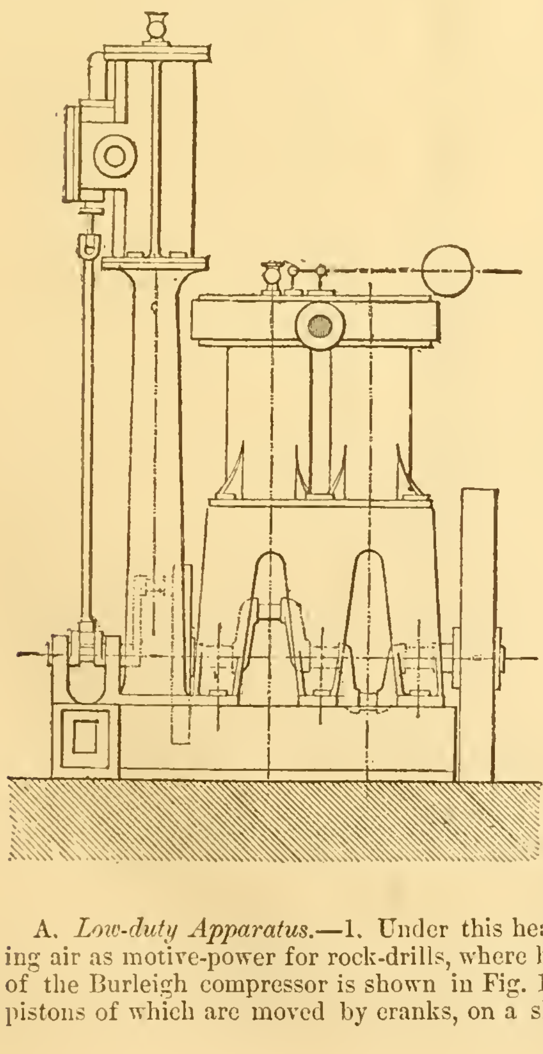


The caissons of the East River Bridge, New York City, were supplied with compressed air by six steam-engines driving two single-acting compressors, with cylinders 14.9 inches in diameter by 13.7 inches stroke. See Caissons.

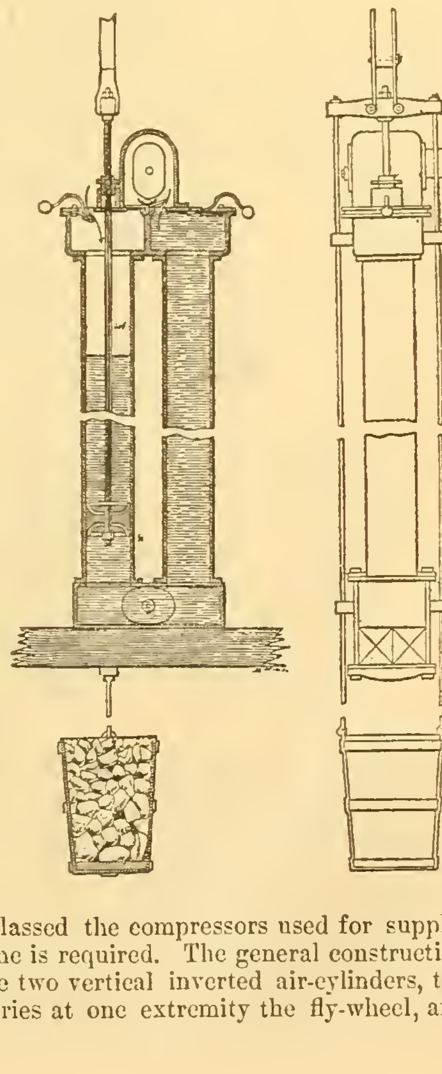
B. *High-duty Machines. Engine for Bessemer Converters.*—Fig. 144 represents an engine of this class, employed in Pittsburg. The cylinders are disposed vertically, the air-cylinder being uppermost and inverted. Around this cylinder is a water-jacket, and the valves are placed in the ends, which, divided by a diametrical partition, constitute inlet and delivery chambers. The valves are formed of very light disks of vulcanized India-rubber, supported by disks of brass. They move on bronze seats inserted in the cylinder-ends, and are held thereon by spheral springs. The dimensions, etc., are as follows: Absolute air-pressure, 2.66 atmospheres; volume of air furnished at this pressure, 2,389 cubic feet. Motor: Diameter of piston, 41 inches; stroke, 47 inches. Air-cylinder: Diameter of piston, 53.4 inches; stroke, 47 inches; useful volume of cylinder, 63.7 cubic feet; revolutions per minute, 50; theoretic volume of air delivered per minute, 6,356 cubic feet.

III. High-Pressure Compressors.—Machines of this class are by far the most numerous. Air employed as a means of transmission of power over long distances is compressed to a pressure of from 4 to 8 atmospheres, in order to enable it to overcome friction of pipes, etc., and to reach the apparatus of which it is the motor with effective working energy.

145.



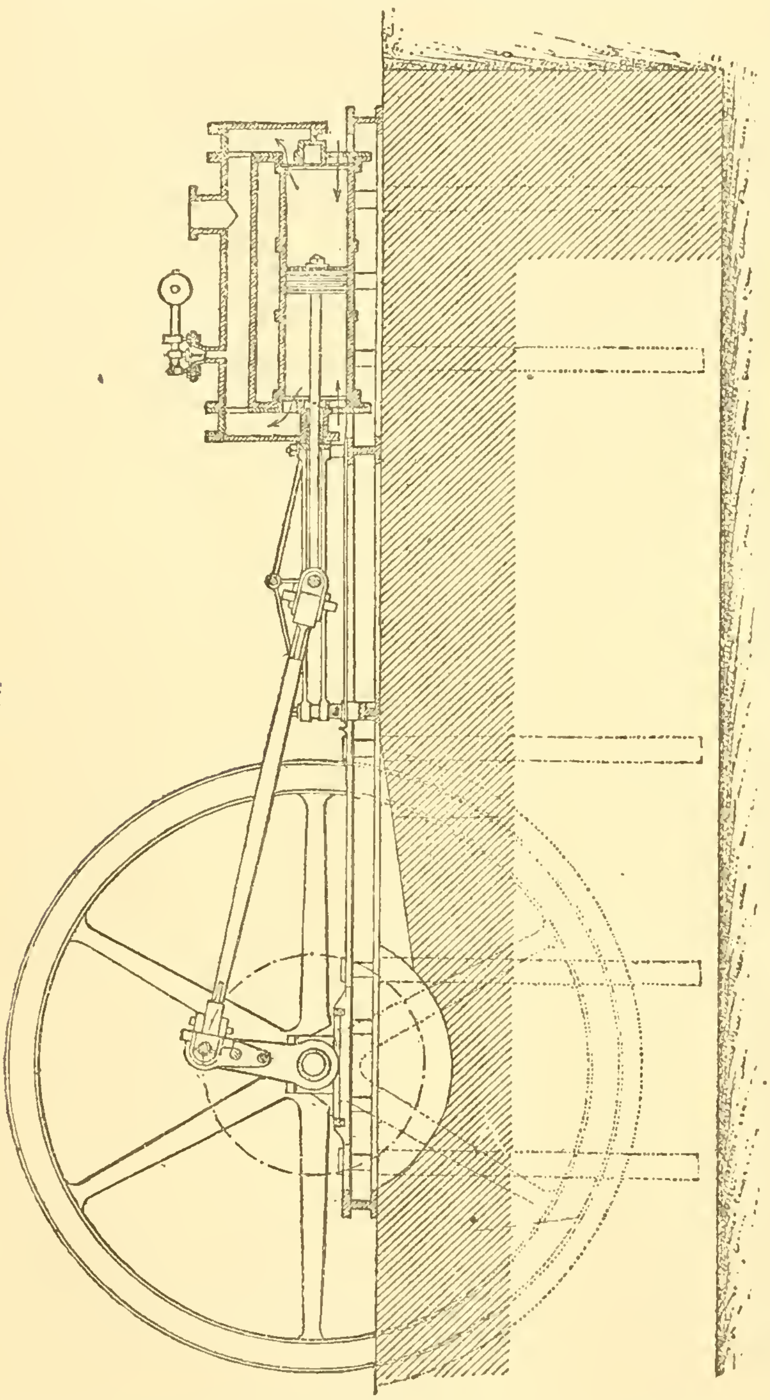
146.



A. *Low-duty Apparatus.*—1. Under this heading may be classed the compressors used for supplying air as motive-power for rock-drills, where but small volume is required. The general construction of the Burleigh compressor is shown in Fig. 145. There are two vertical inverted air-cylinders, the pistons of which are moved by cranks, on a shaft which carries at one extremity the fly-wheel, and

at the other the crank which is connected with a direct-acting inverted engine mounted on the same support. The delivery-valves are placed in a chamber which connects the upper parts of the two cylinders. They are cooled by a stream of water, regulated to quantity by a suitable valve. The machine may be said to furnish 35.3 cubic feet of air, at 4 atmospheres and at 90 revolutions per minute. This is one of the most successful compressors for supplying power to drills yet constructed.

2. *Hydraulic Piston-Compressors.*—The compressor used in the mines of Perseberg, Sweden (Fig. 146), is connected with and actuated by the pumping-engine. It consists of two vertical cylinders connected by a cast-iron bed below, and carrying a valve-box above. In one of the cylinders is the piston which, surrounded by water, causes the liquid at each stroke to rise in one vessel and descend in the other. In order to facilitate the descent of the piston, a cross-head is attached to the piston-rod from the arms—bars extend down on each side and below the apparatus. These bars sustain a counterweight which equilibrates the water in the second cylinder. Simple flap-valves of leather backed with metal are employed. The inlet-valves are counterweighted. The dimensions and data are as follows: Absolute air-pressure, 2.5 atmospheres; volume of air furnished at this pressure, 32.1 cubic feet. Compressor (double-acting): Diameter of piston, 15.6 inches; stroke, 85.8 inches; useful volume of cylinder, 10 cubic feet; number of double strokes per minute, 4; theoretic volume delivered at this velocity, 80 cubic feet.



147.

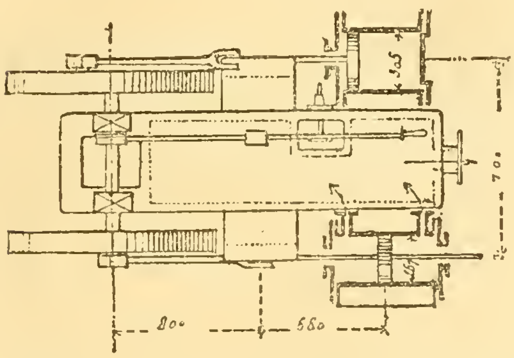
B. *High-duty Apparatus.*—To this class belong the permanent machines for distributing air-pressure as motive-power to numerous points.

1. *Compressors with no Refrigeration.*—When no means of cooling is employed, compressors cannot be advantageously used except for low pressures, and at velocities so far reduced that the heat developed by the compression may be dissipated as fast as generated. It is rarely that a pressure above 2 atmospheres can be reached, working at high speed, as dry air compressed to this degree attains a temperature of 165° Fahr.; or 3 atmospheres working at low velocity as the final temperature of air compressed under this pressure exceeds 266° Fahr. The Sachs compressor (Fig. 147) is an example. In this case the motor (at Vieille Montagne) is an 8-horse-power hydraulic wheel. The useful effort applied to the compressor is 6-horse power, the remainder being otherwise utilized. The piston acts in its horizontal cylinder directly on the air. The three inlet-valves at one end of the cylinder open into the atmosphere; the three delivery-valves in the other end open into chambers which communicate with a cast-iron tube placed parallel to the cylinder. On this is a safety-valve and the connection for the air-conduit. Dimensions and data: Absolute air-pressure, 3 atmospheres; volume of air furnished at this pressure, 47 cubic feet. Air-cylinder. Diameter of piston, 9.7 inches; stroke, 35.8 inches; useful volume of cylinder, 2,730 cubic inches; revolutions per minute, 45; theoretic volume delivered per minute, 143 cubic feet. As compression is not carried to a high degree, the heat generated causes no difficulty.

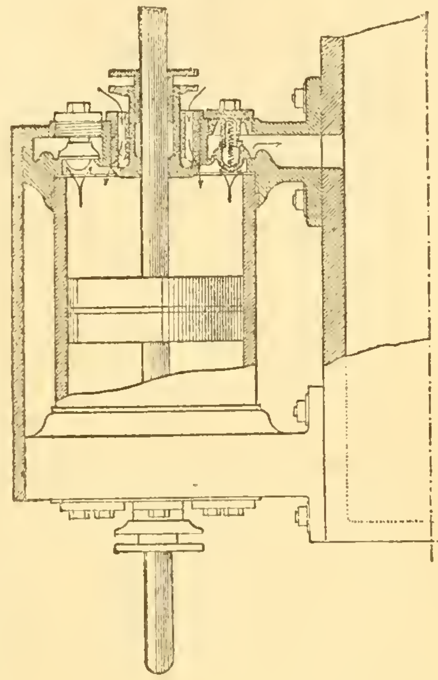
2. *Compressors cooled by Water-Envelope.*—In the majority of compressors the refrigeration is accomplished by jacketing the cylinder and causing a circulation of water in the annular space between. Failure of this means is mostly due to the fact that the air remains dry, and in this

condition the compression causes a development of heat which increases rapidly with the pressure. This heat is incompletely absorbed by the water because of the high velocity with which the air traverses the cylinder, and the consequence is that piston-packing and valves speedily deteriorate. These machines are most advantageously employed for pressures between 3 and 4 atmospheres. One of the most successful compressors of this class is that constructed by Mr. Sturgeon, in England, the disposition of which is shown in Fig. 148. The air-cylinder is attached to one side of a

148.



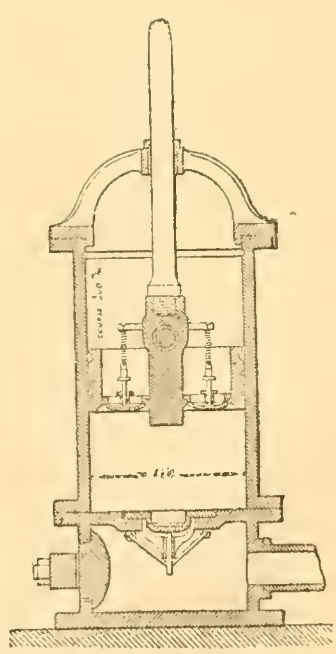
149.



hollow bed or receiver, and is worked by a steam-engine attached to the other side through a crank-shaft carrying a fly-wheel at each end. To these fly-wheels the crank-pins are attached at right angles to each other, so that the piston of the steam-engine may be at the middle of its stroke and the best point of its power, when the piston of the air-engine is approaching the end of its stroke, where it meets the greatest resistance from the compression of the air. The valve-boxes of the air-cylinder (Fig. 149) serve as covers, and are bolted to the receiver. The inlet-valves are at the centre of the boxes. The construction is such that, as the piston begins to recede, the rod carries the valve with it until its progress is checked by a stop, it then being full open, and the rod, continuing its movement through the valve, holds the latter open until the end of the stroke. On the commencement of the return-stroke the valve is at once closed in the same manner. The delivery-valves consist of a number of small valves distributed over the surface of the cylinder-cover or valve-box, and affording a large area of outlet opposite the direction of movement of the piston. The following data relate to one of these compressors exhibited at the Manchester (England) Exhibition of 1874: Absolute air-pressure, 3 atmospheres; volume of air furnished at this pressure, 35 cubic feet. Motor: Diameter of piston, 11.7 inches; stroke, same; diameter of fly-wheels, 3 feet 10 inches. Compressor (double-acting): Diameter of piston, 10.4 inches; stroke, 11.7 inches; useful volume of cylinder, 1,037 cubic inches; revolutions per minute (average), 145—these have been carried as high as 440; theoretic volume delivered per minute, 174 cubic feet.

3. *Compressors refrigerated by Layer of Water on the Piston.*—This mode of cooling is much more efficacious than a simple outside water circulation, because the inner periphery of the cylinder which is in contact with the heated air is kept wet, as a quantity of water passes around the piston which may be sufficient to saturate the air with watery vapor during its compression. In this state, air may be compressed to 7.5 atmospheres without its temperature exceeding 194° Fahr. The portable compressor of MM. Saultier and Lemonnier, a section of which is given in Fig. 150, belongs to this class. It is a small, strong machine, built of sufficiently light weight to be carried by a mule. The cylinders, of which there are two, are open above. A thin stream of water passes to a circular channel in the upper part of the cylinders, by which it is distributed around their inner portion to the pistons, through the inlet-valves, in which it enters into the space in which the air is compressed, so that it comes in direct contact with the air. There are three valves in each cylinder: two inlets in the piston, and one delivery at the cylinder-bottom. They are simply bronze cups on seats of the same metal, provided with suitable springs, and guided by stems, dimensions, data, etc. Absolute air-pressure, 5 atmospheres; volume of air furnished at this pressure by both cylinders, 5 cubic feet 269 cubic inches. Motor of 10-horse power, any form. Compressor: Diameter of pistons, 9.3 inches; stroke, 11.7 inches; useful volume of cylinders, 479 cubic feet; revolutions per minute, 27; theoretic volume delivered by the pistons at this velocity, 26 cubic feet.

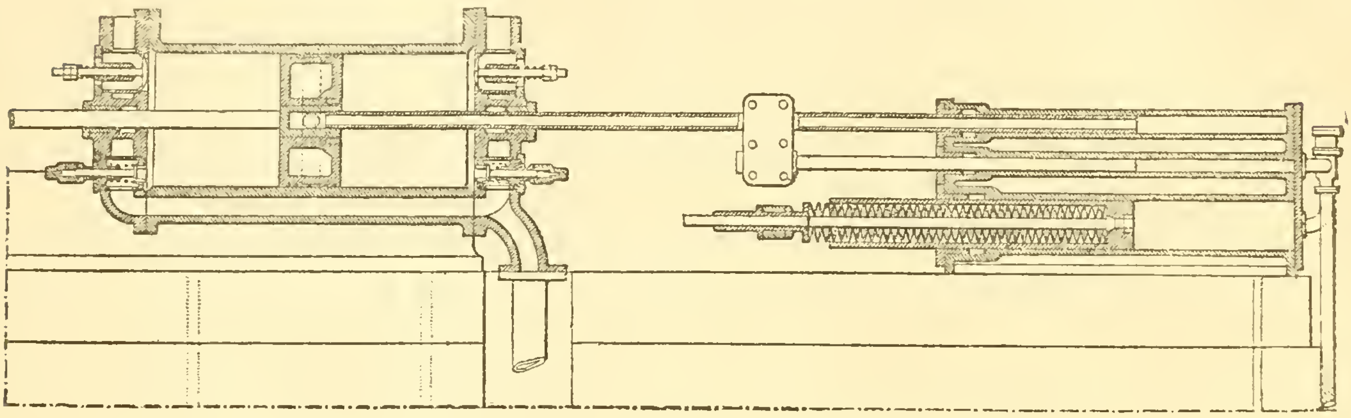
150.



4. *Compressors refrigerated by Water introduced at the Periphery of the Compressing Piston.*—In 1872 Messrs. Benjamin Roy & Co., who built the first air-compressing machines for the St. Gothard Tunnel, adopted a system of construction which involved a hollow compressing piston, receiving by its rod water under pressure which it distributed uniformly over the piston by means of a channel at the

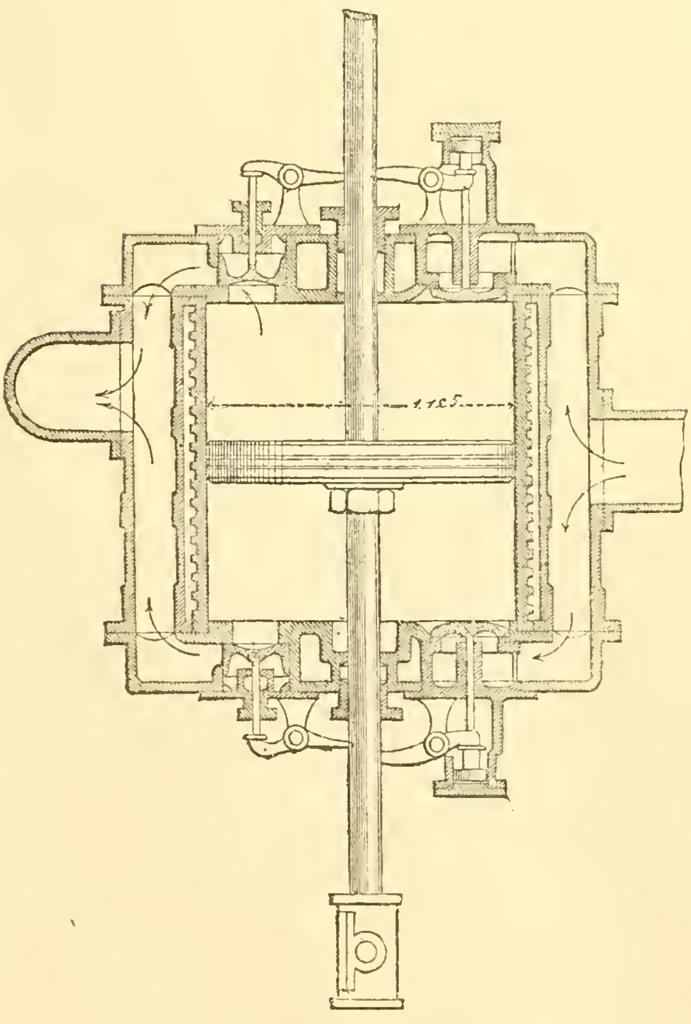
middle. This disposition is analogous to the water-layer on the piston in the preceding class of machines, but it is considered preferable because it is applicable to double-acting, to horizontal, and to fast-running compressors, since the piston is no longer formed of two independent portions, of

151.



which one (the liquid packing) may be disadvantageously affected by high velocities. In Fig. 151 is given a section of the air-cylinder and pump of a compressor of this type, made for mining purposes by the French Compagnie de l'Horme. The piston is hollow, and has on its periphery five channels, of which one communicates by apertures with its interior, and serves as an escape for the water. The others receive the metal packing-rings. In rear of the piston is a hollow rod which is screwed in the piston-rod, and which, passing through the rear cylinder-head, connects with a pump. The latter is composed of two small barrels and a spring accumulator. The pistons consist of two solid rods connected by a cross-piece and a sleeve to the prolonged hollow piston-rod. These plungers pump the water from a reservoir into the accumulator chamber, whence it is forced through the piston-rod and out through the piston, as already described. The water then escapes into a reservoir, in which is an automatic valve, which opens when a certain level is reached, and allows the water to pass into the receptacle, from which it is pumped. Dimensions and data: Absolute air-pressure, 6 atmospheres; volume of air furnished at this pressure by two cylinders, 142 cubic feet. Motor, two direct-acting horizontal cylinders. Diameter of pistons, 19.5 inches; stroke, 31.2 inches. Variable cut-off. Condensing. Fly-wheels, 11 feet 5 inches in diameter. Two double-acting air-compressing cylinders. Diameter of pistons, 15.6 inches; stroke, 31.2 inches; useful volume of cylinders, 3,547 cubic feet; revolutions per minute, 60. Volume delivered at this velocity, one cylinder, 422 cubic feet; two cylinders, 844 cubic feet.

152.

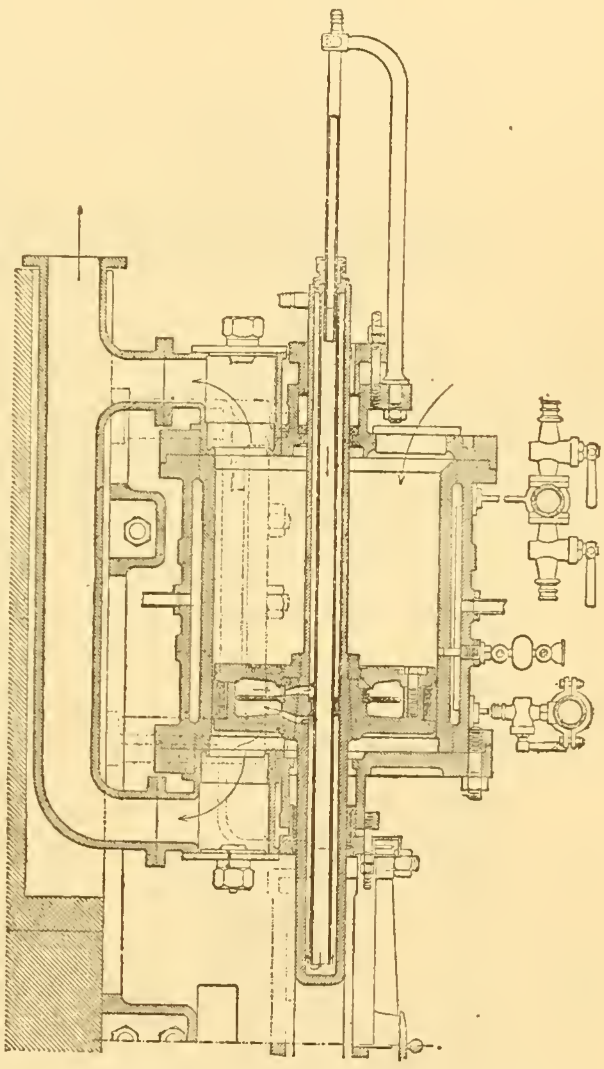


5. *Compressors refrigerated by Injection of Water in the Cylinder.*—This system is better than the foregoing, because the air becomes more perfectly saturated with watery vapor. The compressing cylinder of the Windhausen machine (see REFRIGERATING MACHINERY) is of this class, and is represented in Fig. 152. The cylinder has a double envelope in which cold water circulates. In order to augment the surface exposed to the action of the water, grooves are made close together on the outside of the interior shell. Four valves, placed in each end of the cylinder, are contained in the covers, which form chambers, and are connected by horizontal tubes, whence lead the air-ducts. The two inlet-valves placed at the upper part of the cover are guided by stems which carry small pistons moving in closed cylinders, in which the air forms an elastic cushion. A lever, actuated by traverse-guides on the piston-rod, moves these stems so as completely to close the inlet-valves when the piston reaches the end of its stroke. The two delivery-valves at the lower part of the

cylinder are composed each of a cylinder of bronze closed by a lightly concave bottom. This cylinder travels in another closed cylinder in which the air-spring tends to maintain the valve upon its seat. These valves are also guided by stems terminated by a projection with which a lever comes in contact so as to lift the traverse guide of the piston at the end of each aspirating stroke. The cooling of the air is directly effected in the cylinder by a jet of cold water which enters at the upper portion of each end of the cylinder through an aperture made between the two inlet-valves. This injection is produced by small pumps placed laterally at each end of the cylinder, the pistons of which are actuated by the air compressed in the cylinder, so that the intensity of the jet increases with the degree of compression of the air. Dimensions and data: Absolute air-pressure, 5 atmospheres; volume of air per minute furnished at this pressure, 371 cubic feet. Motor, single horizontal cylinder communicating with compressor; compressor horizontal, double-acting. Diameter of piston, 43.6 inches; stroke, 41 inches; useful volume of cylinder, 37.1 cubic feet; revolutions per minute, 25; theoretic volume at this velocity, 1,858.5 cubic feet.

6. *Compressors refrigerated by Injection of Water in Form of Spray into the Cylinder* (Fig. 153).—Four sets of compressing cylinders, three in each group, and all belonging to this type, are in use at Airolo, St. Gothard Tunnel. To each group motive power is communicated from gearing connected with the shaft of a turbine wheel. There is a circulation of water in the head and around each cylinder, and also in the piston and rod, besides an injection of spray at each end. The circulation around the body and ends of the cylinders is obtained from small pumps operated from the rod of the compressing piston. This pump injects water into the hollows in the cylinder-ends and into the annular space formed around the cylinder by a sheet-iron envelope. The piston-rod, which is of steel, is bored through to receive a copper tube of smaller diameter. This tube is nearly as long as the rod, and is connected to it at the rear end by a screw-threaded bronze plug. The mode of connection at the opposite extremity is clearly shown in the drawing. The water injected by the pump passes through this tube and returns by the annular space between the tube and piston-rod, as far as a diaphragm which is formed of a bronze ring fixed on the rod just inside the piston, and which compels the water to penetrate the latter, cooling the two faces as indicated by the arrows. This water then escapes by the rubber tube attached to the rear end of the piston-rod. The water which enters at each end of the cylinder does so through spouts so constructed that two fine streams are emitted by each, and the two jets on escaping are caused to meet at nearly a right angle, so that the water becomes turned to spray by the impact. The quantity of water introduced is regulated so as to maintain the air completely saturated. Under these conditions, even when circulation inside the piston is not continuous, it has been found possible to maintain the temperature of the entire apparatus at about 86° Fahr. Three valves are placed at each end of the cylinder, two inlet and one delivery. The total area of the inlet-valves is .11, and of the delivery-valves .04, that of the piston-surface. Dimensions and data: Absolute air-pressure, 6 atmospheres; volume of air furnished at this pressure by the three compressors of a group, 236.9 cubic feet. Motor for each group turbine of 46.8 inches diameter, under 528 feet head velocity, 390 turns per minute. Transmission by gearing in ratio of 1 to 4.35. Triple compressors, double-acting. Diameter of pistons, 17.9 inches; stroke, 17.5 inches; useful volume of cylinders, 26.4 cubic feet; revolutions per minute, 90; theoretic volume delivered at this velocity for each compressor, 475.2 cubic feet. Final temperature of air on leaving cylinders, 104°. It will be seen that the four groups of compressors employed produce at the above average velocity of 90 revolutions 947,600 cubic feet of air at a pressure of 6 absolute atmospheres.

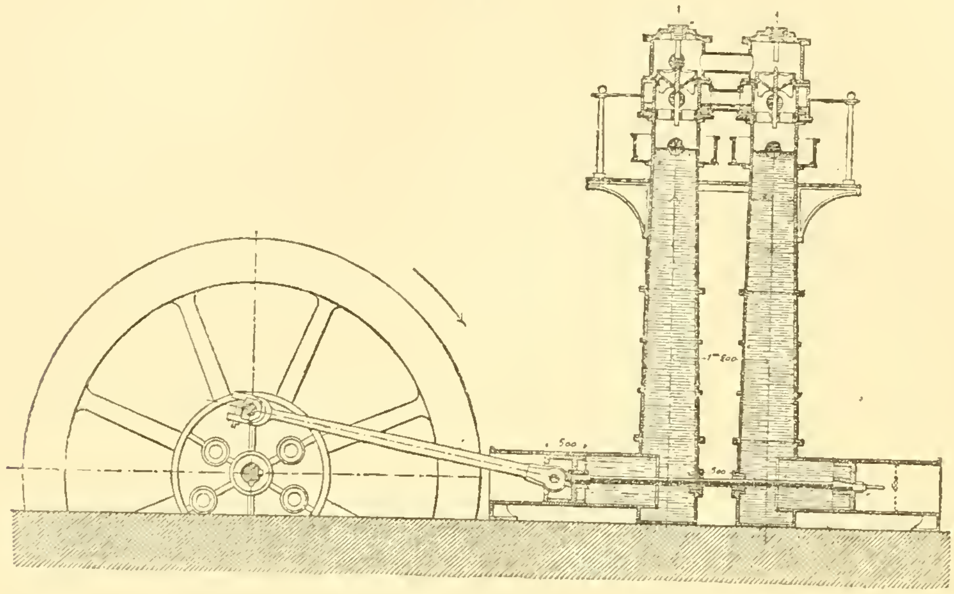
153.



7. *Hydraulic Piston-Compressors.*—An example of this type is the improved Sommeiller compressor used in the tunneling of Mont Cenis, as shown in Fig. 154. The two cylinders of each compressor are isolated, and each has its own piston, only one of the faces of which (that in contact with the water, and which, by the intermediation of the latter, acts on the air) is concealed, while the other is easily accessible in the pump-body in which it moves. The piston is very long, so that it guides itself. The valves consist of four circular leaves of leather with metallic backing, resting on an inclined bronze seat. These are disposed, two by two, along the vertical column of the compressor, as shown in the engraving. The upper ones are the inlet-valves, and take air from a cylindrical iron

envelope which communicates with the atmosphere. The lower valves open into a water-box, and serve for the introduction of water to replace that entrained by the compressed air. The delivery-

154.

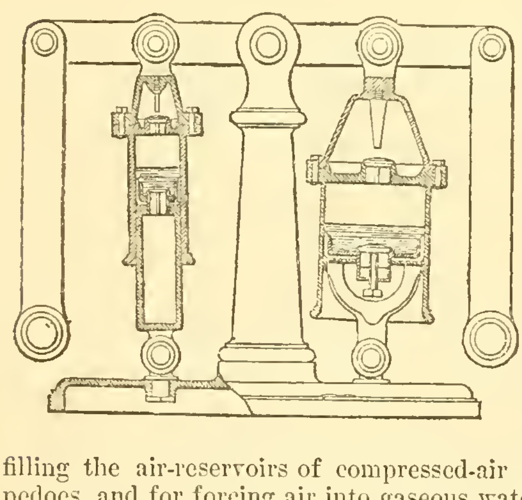


valve is of bronze, and conical. Dimensions and data: Absolute air-pressure, 7 atmospheres; volume of air furnished at this pressure by the two compressors connected to a single hydraulic wheel, 68.4 cubic feet. Motor, hydraulic wheel, 216 inches in diameter, and 163.8 inches in breadth, discharging 35.3 cubic feet of water per second, under a head of 216 inches. Direct crank-connection. Compressor: Piston-diameter, 23.4 inches; stroke, 58.5 inches; useful volume of cylinders, 14.9 feet; number of turns per minute, 8; theoretic volume of air delivered at this velocity, 476.55 cubic feet. Final temperature of air on leaving compressors, 104° Fahr.

8. *Shock-Compressors.*—These machines are not used industrially, on account of their inefficiency. They are really nothing but hydraulic rams of large size. They were used for a time at the Mont Cenis Tunnel, but were removed to give place to piston-compressors.

IV. Very High-Pressure Compressors.—Compressors belonging under this division are not largely employed for industrial purposes. They are utilized for compressing air to a great degree in small reservoirs, such as are carried by divers, when the latter take with them their own air-supply, instead of depending on pumps at the surface. They are also used for compressing gases in cylinders which are delivered to consumers, for the oxyhydrogen light, etc.; also for filling the air-reservoirs of compressed-air locomotives and of torpedoes, and for forcing air into gaseous waters.

155.



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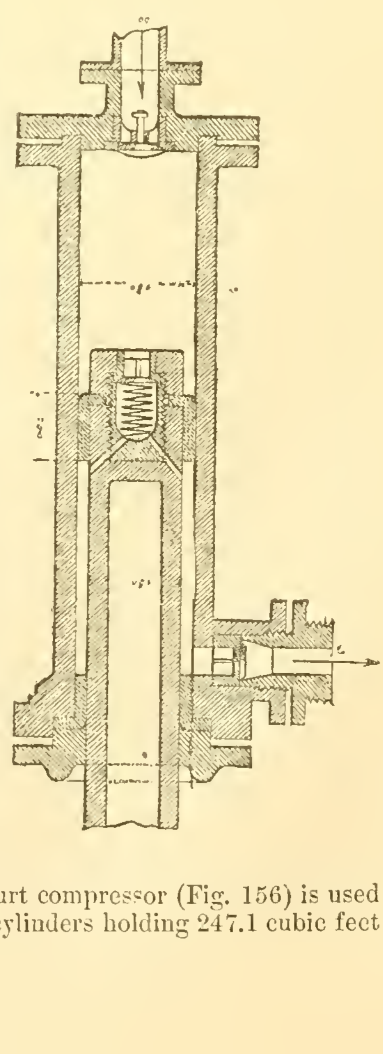


A. *Low-duty Apparatus.*—M. Rouquayrol's pump (Fig. 155) is adapted to filling reservoirs of air for divers, of a capacity of something less than a cubic foot, with air under 40 atmospheres' pressure. The apparatus is composed of two pump-bodies of unequal diameter. The first has large diameter and long stroke; the second, a much smaller diameter, and a stroke reduced, so that the volume delivered by the piston of the large body may be five times greater than that delivered by the small piston. The air compressed by the large piston is forced into a small reservoir forming the upper portion of the pump-body; and it is in this reservoir that the small piston carries the pressure from 5 atmospheres to 25. With an apparatus of four such differential bodies, a pressure of 100 atmospheres may be obtained by man-power. The valves have water-joints, and all the connections are made with great accuracy.

B. *High-duty Apparatus.* 1. *Direct-action Machines.*—The Hurcourt compressor (Fig. 156) is used in Paris for compressing gas, at a pressure of 11 atmospheres, into cylinders holding 247.1 cubic feet

each. The apparatus consists of two single-acting pumps, disposed on each side of a pyramidal support, which carries at its summit a shaft with cranks at right angles, and a belt-pulley between the two standards. The cylinder is of cast-iron, with no exterior envelope, and no means of refrigeration. At the base is a tube, in which is the conical inlet-valve. Opening into the piston is a conical valve which communicates by three openings leading through the rod, and just above the piston-packing, with the annular space between rod and cylinder. The piston, on descending, compresses the gas contained in the pump-body, until a pressure is reached sufficient to enable the gas to lift the valve in the piston and pass into the annular space above. On the up-stroke of the pump the gas is again compressed, and at the same time a new supply is drawn in through the valve in the cylinder-bottom. Dimensions and data: Absolute air-pressure, 11 atmospheres; volume of compressed gas furnished at this pressure by the two pumps, 2,939.7 cubic feet. Motor, horizontal non-condensing engine—no steam expansion—connects with 6 compressors by belting. Diameter of piston, 13.26 inches; stroke, 24.9 inches; steam-pressure, 6 atmospheres; revolutions per minute, 70. Compressor: Diameter of piston, 7.02 inches: stroke, 23.4 inches; useful volume of cylinder, 538.6 cubic feet; revolutions per minute, 30; theoretic volume generated at this velocity by each compressor, 32,337.6 cubic feet.

2. *Hydraulic Piston-Compressors.*—The machines under this class are but two: one, a very old apparatus, not used at present; in the second, in which the air is compressed to 25 atmospheres, the refrigeration is accomplished by injection, and the compression effected in two unequal cylinders. This machine has not been subjected to sufficient practical tests to admit any authentic data being presented.

*Summary.*—In the construction of air-compressors, the present tendency is to use metal throughout. For piston-packing, rings or segments in cast-iron or bronze are employed; for stuffing boxes, soft alloys, and for valves in machines for distributing power, plates of steel, resting in bronze seats, either with or without springs, are recommended. With regard to dimensions, starting with the volume of compressed air to be furnished per minute under a given pressure, the useful volume to be given to the compressor is first to be calculated, keeping in view the fact that the compressing piston, if on the hydraulic system, should not travel faster than 15 revolutions per minute; or, if direct-acting, not more than 60 revolutions. The useful volume determined, the stroke of the piston is fixed so that the velocity per second shall not exceed 29.25 inches for hydraulic piston-compressors, or 58 inches for direct-acting compressors. If the diameter is too large, two cylinders are employed.

*Results of Tests.*—From the records of a large number of experimental investigations, the following results are selected: I. Apparatus without piston—1. Machines acting by simple displacement of water: useful effect, 6 to 40 per cent.—Experiments of MM. Romilly and Worms (*Annales des Mines*). 2. Entrainment apparatus: useful effect, 41.50 per cent.—Same experimenters. II. Hydraulic piston apparatus—Sommeiller compressor improved: useful effect, 84 per cent.—Daxhelet's experiments (*Revue Universelle des Mines*). III. Apparatus with piston acting directly on air—London Pneumatic Telegraph compressor: useful effect, 87 per cent.—Tested by constructor (*Engineering*, 1874). Schacht compressors, Saarbrück mines: air compressed to 4 atmospheres, 80 per cent. In power utilizable at driven shaft of compressor, with expansion of one-half, about 40 per cent.; at 3 atmospheres, 84½ per cent.; at 1 atmosphere, 91 per cent.—Hasslacher's experiments (*Annales des Mines Prussiennes*, vol. xvii.). Ryhope Colliery compressor: average useful effect, 66 per cent.—Taylor's experiments (*Transactions of North of England Institute of Mining and Mechanical Engineers*, vol. xxi.). As a rule, it may be stated that the useful effect of the most improved compressors is 80 per cent. at average rate of travel.

Distribution of Compressed Air. *Tubing.*—Tubes are usually of cast or wrought iron, the former being preferable for large diameters, and the latter for those below 3.9 to 5.7 inches. Wrought-iron has the advantage of lightness and flexibility. Tubes of riveted sheet-iron are sometimes used for transmitting blast to furnaces. Copper tubing is employed where flexible joints and sections of peculiar shape are needed. Lead tube is of little value, and rubber tubes are used for flexible connections. The latter are usually lined with wire-spiral, and covered with canvas. *Diameter of Tubing.*—The following table shows the losses of pressure in millimetres of mercury which occur in conduits 1,000 metres in length, and of diameters increasing from .1 to .35 metre, velocity of air from 1 to 6 metres:

| Velocity of the air at opening of conduits, in metres, per second. | Losses of pressure in millimetres of mercury observed in conduits of 1,000 metres in length and of interior diameters of | | | | | |
|---|---|---|---|---|---|---|
| | .1 metre. | .15 metre. | .2 metre. | .25 metre. | .3 metre. | .35 metre. |
| 1 | 6 | 4 | 3 | 3 | 2 | 2 |
| 2 | 26 | 18 | 13 | 11 | 9 | 8 |
| 3 | 62 | 42 | 31 | 25 | 21 | 18 |
| 4 | 108 | 72 | 54 | 44 | 36 | 31 |
| 5 | 167 | 112 | 84 | 67 | 56 | 48 |
| 6 | 233 | 156 | 117 | 94 | 78 | 67 |

The results of practice at the tunnels of Mont Cenis and St. Gothard, Saarbrück mines, and elsewhere in Europe, show the following diameters of pipes to be advisable: For principal conduits, cast-iron, from 5.8 to 9.7 inches; for secondary conduits (generally drawn tubing), 2.9 to 5.8 inches; for extreme branches (always drawn tubing), 1.9 to 2.9 inches; for flexible connections (rubber), 0.9 to 1.9 inch.

*Reservoirs.*—Under ordinary conditions, the capacity of the reservoir should represent 10 or 15 times the consumption of air in cubic feet per minute when the air is used variably, as in rock-drills; in cases of regular employment, 4 or 5 times the consumption per minute may be taken as the rule. In a large number of instances, reservoirs ranging from 706 to 2,824 cubic feet have been found of ample size.

*Duty of Air-Motors.*—In many English mines experiments have been conducted with a view to

determining the fraction of absolute work theoretically transmitted by air delivered, which machines, driven by said air, return in the form of effective work. This work has always represented 55 to 75 per cent. of the absolute work, which corresponds to the consumption of compressed air. At St. Gothard Tunnel, M. Rebourt, by direct experiment upon compressed-air locomotives, determined that the relation of tractile work to the theoretic work of air expended was comprised between .50 and .60. If, instead of seeking a ratio between the effective work and the theoretic work contained in the air expended, we determine the same between the first and the work expended to compress the air so as to obtain the total useful effect of the entire system, or, in other words, for the fraction of work expended by primary motor which is returned from the shaft of the compressed-air engine, the relation is found to be between 20 and 25 per cent. at high pressure, or 35 and 40 per cent. at low pressure.

*Works for Reference.*—The foregoing article is translated and abridged from *L'Air Comprimé*, by A. Pernolet (Paris, 1876), to which the reader is referred for complete discussion of the subject. For a full list of all the authorities on compressed air, reference may be had to "Tunnelling, Explosive Compounds, and Rock-Drills," by H. S. Drinker, E. M. (New York, 1878).

AIR-CHAMBER. See Pumps.

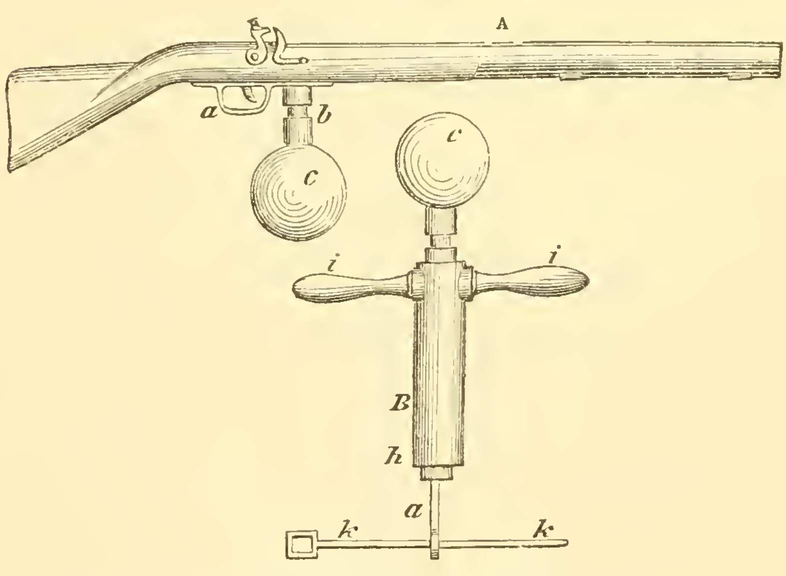
AIR-ENGINE. See Engines, Air.

AIR-ESCAPE. A simple and ingenious contrivance for letting off the air from water-pipes. If a range of water-pipes be led over a rising ground, it will be found that air will collect in the higher parts and obstruct the progress of the water, to remedy which inconvenience the air-escape is employed. A hollow vessel is attached to the upper part of the pipe, in the top of which vessel there is fixed a ball cock, adjusted in such a way that, when any air collects in the pipe, it will ascend into the vessel, and, by displacing the water, cause the ball to descend, and thus open the cock, when the air is allowed to escape. No water, however, can escape, for, when that fluid rises in the vessel above a certain height, the ball rises and shuts the cock; new air then collects, displaces the water, lowers the ball, the cock is opened, and it again escapes.

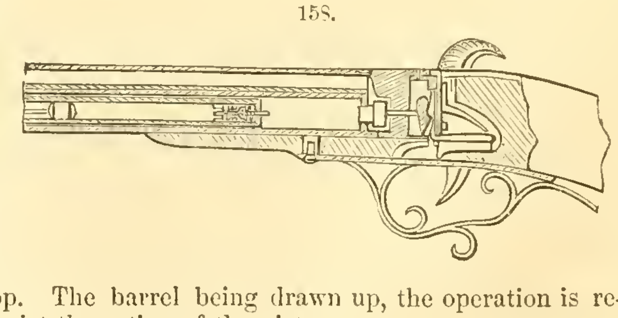
AIR-GUN. A machine in which highly-compressed air is substituted for gunpowder to expel the ball, which will be projected forward with greater or less velocity, according to the state of condensation and the weight of the body projected.

It consists of a lock, stock, barrel, ramrod, etc., of about the size and weight of a common fowling-piece. Under the lock at *b* is screwed a hollow copper ball *c*, perfectly air-tight. This ball is fully charged with condensed air, by means of the syringe *B*, previous to its being applied to the tube at *b*. Being charged and screwed on as above stated, if a bullet be rammed down in the barrel, and the trigger *a* be pulled, the pin in *b* will, by the spring-work in the lock, forcibly strike out into the ball, and thence, by pushing it suddenly, a valve within it will let out a portion of the condensed air, which, rushing through the aperture in the lock, will act forcibly against the ball, impelling it to the distance of 60 or 70 yards, or farther if the air be strongly compressed. At every discharge only a portion of the air escapes from the ball; therefore, by re-cocking the piece another discharge may be made, which may be repeated for a number of times proportioned to the size of the ball. The air in the copper ball is condensed by the syringe *B* in the following manner: The ball is screwed quite close on the top of the syringe; at the end of the steel-pointed rod *a* is a stout ring, through which passes the rod *k*; upon this rod the feet should be firmly set; then the hands are to be applied to the two handles *i i* fixed on the side of the barrel of the syringe, when, by moving the barrel *B* steadily up and down on the rod *a*, the ball *c* will become charged with condensed air, and the progress of condensation may be estimated by the increasing difficulty in forcing down the syringe. At the end of the rod *k* is usually a square hole, that the rod may serve as a key for attaching the ball to either the gun or syringe. In the inside of the ball is fixed a valve and spring, which gives way to the admission of the air, but upon its emission comes close up to the orifice, shutting out the external air. The piston-rod works air-tight by a collar of leather on it, in the barrel *B*; it is therefore obvious that, when the barrel is drawn up, the air will rush in at the hole *h*; when it is pushed down, it will have no other way to pass from the pressure of the piston but into the ball *c* at the top. The barrel being drawn up, the operation is repeated, until the condensation is so great as to resist the action of the piston.

157.




158.

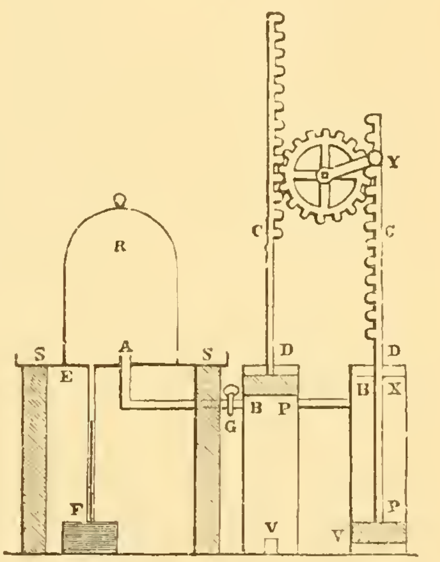


In Gifford's air-gun, Fig. 158, the barrel is in communication with the inside of the trigger-box, in the interior of which is a valve-piston, consisting of a steel rod carrying a ring fitted with a caoutchouc disk for closing communication. Air enters the barrel by a bell-shaped chamber. By pressing strongly on the extremity of the rod, the disk is compressed and closes the reservoir-orifice. By suddenly releasing the piston-valve, the elasticity of the rubber, combined with the pressure of the air, causes the sudden opening of the reservoir-orifice, and emits a blast of air to the rear of the projectile. The air is compressed into a reservoir beneath the barrel by means of a piston working longitudinally in a valved interior tube.

AIR-PIPES. An invention for clearing the holds of ships and other close places of their foul air. The contrivance is simply this: A long tube, open at both ends, is placed with one end opening into an apartment to be ventilated, and the other out of it. The air in the outer end of the tube is rarefied by heat, and the dense air from the hold comes in to supply the partial vacuum, the escape of the foul air in the hold being supplied by fresh air introduced through an opening above; and this process is carried on until the air becomes everywhere equally elastic.

AIR-PUMP. The air-pump is an instrument by which a vacuum can be produced in a given space, or rather by which air can be greatly rarefied, for an absolute vacuum cannot be produced by its means. Fig. 159 represents a simple form of this machine. Through the centre of the brass plate there is drilled an orifice *A*, from which orifice there is led a pipe *A B*, forming a communication between the receiver *R* and the interior of the cylinder *B P V*, which communication may be opened or closed by means of a stopcock at *G*. The cylinder or barrel *B P V* is furnished with a piston *B P* accurately fitted to the cylinder, but capable of free motion up and down, which motion is effected by means of a piston-rod *D C*, which moves through a stuffed or air-tight collar at *D*. The bottom of the cylinder or barrel is furnished with a valve *V* opening outward. This cylinder communicates with another *B X P V*, constructed and furnished in a similar manner; and the two piston-rods are provided with racks *C C* at the top, the teeth of which are acted upon by those of a wheel placed between them, as may be seen in the figure. Let us now attend to the mode of action. Suppose the stopcock at *G* open, and the pistons as they are in the figure. The piston *B P* being at the top, a free communication is formed between the receiver *R* and the first cylinder, and the piston being pushed down past the orifice at *B*, the air contained in the cylinder or barrel will be forced into less space or compressed, and, of course, its elastic force increased. In consequence of this increased elasticity, the valve at *V* will be opened and the air expelled. When the piston is lifted, this valve will be shut by the pressure of the atmospheric air without; thus a portion of the air which was contained in the receiver, communication-pipe, and barrel, has been expelled, and that which remains will consequently be less dense; another stroke of the piston will diminish the density still more; and this process may be continued until the density be so diminished that, when compressed by the descent of the piston to the bottom of the barrel, its elastic force is only sufficient to open the valve *V*. It will be easily seen that the exhaustion of the air in the receiver depends on the elasticity of the air; for when the piston descends and expels the air contained within the barrel, which it will do completely if it go to the bottom, and then, in returning, the valve *V* being shut, a vacuum will be formed in the barrel until the piston in its ascent passes the orifice *B*, when the air within the receiver will expand and fill the whole cavity. The operation of the second barrel and piston is precisely similar to that of the first, so that when the one is understood, the other requires no explanation.

159.

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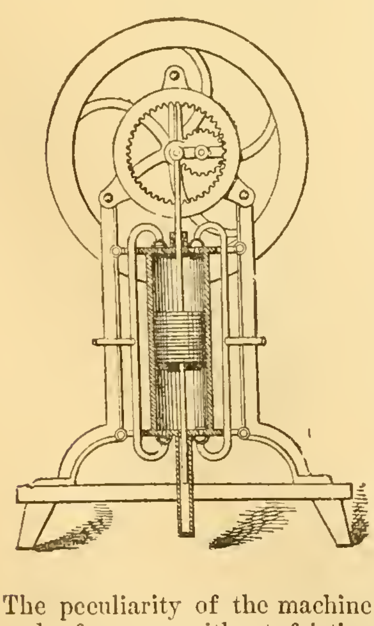


The degree of exhaustion will depend upon the workmanship of the pump, the number of strokes of the piston, and the relative capacities of the receiver and barrels; but perhaps in no case can the vacuum in the receiver be made perfect. For the purpose of determining the degree of exhaustion, a mercurial gauge is employed, which acts on a similar principle with the common barometer. A glass tube *E F* rests in a basin of mercury *F*, and its upper orifice opens into the brass plate *S S*. When the exhaustion of the receiver has commenced, the pressure of the air in the receiver must be less than that of the atmosphere without. Wherefore, since the air in the receiver presses the mercury down the tube, and the atmosphere pressing on the mercury in the basin forces it up the tube, with the greater force the mercury will rise in the tube, and it will rise the higher according to the difference of the density, and consequently elastic force, of the air in the receiver, and that of the atmosphere.

Two examples of the latest improved air-pumps are given herewith. Fig. 160 is the free-piston air-pump of M. J. A. Deleuil. The peculiarity of the machine is that the piston works out of contact with the barrel of the pump, and, of course, without friction. The film of air between piston and cylinder-wall forms a kind of

lubricating cushion. The piston is driven by an epicycloidal combination operated by crank and fly-wheel, and is guided by its rod, as shown. There are two valves at each end of the cylinder, one opening inward, the other outward. The outward-opening valves both communicate with the same tube, which is secured and united with the cylinder at both extremities. At the middle point of this tube a branch leading from it may be connected with a condensing apparatus; so that the pump may be used for condensation as well as rarefaction. When used for the ordinary purposes of an air-pump this branch is open to the atmosphere. On the other side, the two inward-opening valves are similarly connected, and the branch tube on that side establishes communication with the receiver to be exhausted. The valves are opened and shut mechanically by the piston itself in a manner not shown in the figure. For this purpose two cylindrical rods are introduced passing through the piston, and reaching from end to end of the cylinder, but capable of a slight longitudinal movement as the piston changes its direction. This movement opens a valve at one end, and simultaneously closes the corresponding one at the opposite end; but this change having been effected, the rod remains stationary, the piston sliding on it in continuing its movement. With a machine of this kind, having a cylinder $4\frac{1}{2}$ inches in diameter, a 20-gallon receiver may be exhausted down to a pressure of less than half an inch of mercury in five minutes.

161.

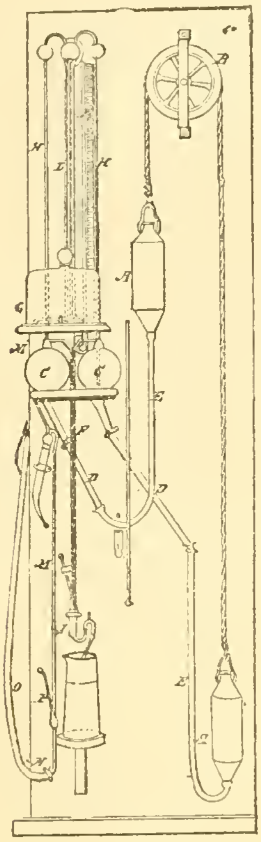
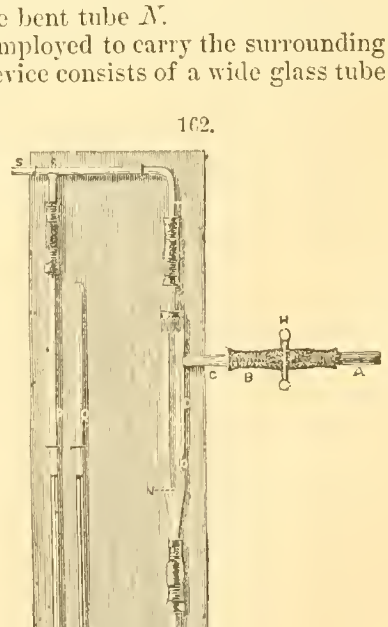


Fig. 161 represents an air-pump devised by M. de las Marismas, which may be cheaply constructed. Two reservoirs *A A* counterpoise each other, and are supported by the pulley *B*. They communicate with two glass balloons *C* by means of the glass tubes *D*, and of the India-rubber tubes *E*. They are filled with mercury, which, when one of the reservoirs is lifted, passes into the balloon and drives the air out of it through the capillary tube *F*, which is soldered to the top, at the same time that the other reservoir, in falling lower than 29.64 inches, causes the mercury to quit the other balloon, thus forming a barometric vacuum. The balloons communicate with the plate *G* by the glass tubes *H*, which plunge to within 0.39 inch of the bottom of the balloons. They are automatically closed as soon as the mercury rises within the balloons to drive out the air, and opened as soon as it retires to produce a vacuum. The air cannot reënter the balloons by the tubes *F* after having been once driven out, because, in order to escape by the orifice *I*, it is obliged to pass through a slight layer of mercury contained in the curved tube *J*; and when the vacuum is formed in the balloons, the atmospheric pressure causes the mercury to mount up again in the tubes, and thus prevents the return of air. In order to receive the air or gas contained in the plate, all that is to be done is to place the required recipient in communication with the orifice *I*. The degree of vacuum produced is indicated by the barometer *K*, which communicates with the plate by tube *L*. The return of the air is effected through the tube *M*, which communicates on one side with the plate, and on the other plunges into the mercury contained in the bent tube *N*.

*Bunsen's Air-Pump* is represented in Fig. 162. Falling water is employed to carry the surrounding air with it, and in this way a steady exhaustion is produced. The device consists of a wide glass tube *D* in which a narrower tube reaches downward to *N*, connected at the top by a well-fitting cork *M*. Water is carried in by a side branch *C*, connected by means of an India-rubber tube *B*, closed by a spring *H*, with a tube *A* drawing water from a reservoir. The current of this water going down in the tube *D* around the inner tube draws the air from *T* and *S* and from any vessel connected with *S*. To increase the effect, the wide tube *D* is connected below with a lead tube *F* which reaches 20 or 30 feet down; so that this long descending column of water acts like a powerful continuous piston.

162.




AIR-SHIP. A vessel adapted to the navigation of the air. The subject will be considered under the two heads of *Balloons* and *Flying-Machines*.

*The Balloon* is a bag or hollow vessel of light impermeable material, which, when filled with a gas lighter than air, ascends. The theoretical considerations governing this result are as follows:

1. If a body is wholly immersed in any fluid, it will be pressed upward by a force equal to the weight of a volume of the fluid equal to the volume of the body.

2. If the upward pressure is less than the weight of the body, the latter will have a tendency to fall, under the action of a force equal to the difference between the body's weight and the weight of an equal volume of the fluid.

3. If the upward pressure is equal to the weight of the body, the body will have no tendency either to fall or rise.

4. If the upward pressure is greater than the body's weight, the body will have a tendency to rise, due to a force equal to the difference between the weight of a volume of fluid equal to the volume of the body, and the weight of the body. These principles are a concise statement of the theory of a balloon's action. If we have a body whose weight per cubic foot is less than the weight of a

cubic foot of air, the body will rise with a force equal to the difference between the body's weight and the weight of an equal volume of air. For instance, if a balloon is filled with hydrogen, the air will exert a lifting force of about $\frac{7}{100}$ of a pound for each cubic foot in the volume of the balloon, so that, if the weight of the balloon and car is less than this lifting force, the balloon will ascend. If common illuminating gas is used in the balloon, the lifting force will be about one-twenty-fifth of a pound for each cubic foot of the balloon's volume. The weight of the material in a balloon varies greatly, of course, according to the construction, some balloons only weighing, with the network, about one-twentieth of a pound per square foot of surface, or even less, and others weighing as much as one-eighth of a pound per square foot of surface. The ordinary shape of a balloon approximates closely to that of a sphere, which it is commonly assumed to be in making calculations.

These rules may be applied in examples in order to exhibit the calculations involved in the designing of a balloon. A balloon has a diameter of 40 feet; the weight of the material and netting is one-eighth of a pound per square foot of surface; the weight of the car and contents is 600 lbs.; and the gas which distends the balloon is subject to an upward pressure of one-twenty-fifth of a pound per cubic foot.

The volume of the balloon is 33,510 cubic feet, so that the upward pressure due to the air is about 1,340 lbs. The surface of the balloon is 5,026.5 feet, so that the weight of material and netting is about 628 lbs., to which must be added the weight of the car, making a downward pressure of 1,228 lbs.; hence the unbalanced upward pressure, which causes the balloon to ascend, is about 112 lbs. It will now be evident that the lifting force of a balloon is entirely due to the air, and is impeded, instead of being assisted, by the gas; so that it would be better, if it were practicable, to make a balloon with a vacuum in the interior. It must be remembered that, as a balloon ascends above the earth's surface, the air in which it is immersed grows continually less dense, so that the lifting force becomes less and less, unless the volume of the balloon is increased. Thus, at about 18,000 feet elevation, the air is only about half as dense as at the sea-level; at 36,000 feet elevation, $\frac{1}{4}$ as dense, and so on. Hence balloons are rarely filled at the surface.

In making the estimate for a balloon, one can generally ascertain the weight of the car and contents, the difference of weight of a cubic foot of air and of the gas to be employed (which may be called the buoyant effort), and the weight of the balloon with its ropes and network per square foot of surface. It is then required to find the diameter of a balloon which will have a tendency to rise with a given force. The calculation by which this is determined is somewhat complex, but it will be found explained at length below, an example being added for the purpose of further illustration. The following quantities must first be ascertained: 1. The buoyant effort, or difference between the weight of a cubic foot of air and of gas. 2. The weight, which includes the weight of everything except the material of the balloon and the netting, together with the lifting force. 3. The superficial weight, or weight of the material and netting, per square foot of the balloon's surface.

The operations for finding the required diameter are as follows: (*a*) Divide twice the superficial weight by the buoyant effort. (*b*) Divide 8 times the cube of the superficial weight by the cube of the buoyant effort. (*c*) Divide 0.95493 times the weight by the buoyant effort. (*d*) Multiply 15.27888 times the cube of the superficial weight by the weight, and divide the product by the fourth power of the buoyant effort. (*e*) Divide 0.91188 times the square of the weight by the square of buoyant effort. (*f*) Add together the quantities obtained by rules (*d*) and (*e*), and take the square root of the sum. (*g*) Add together the quantities obtained by rules (*b*), (*c*), and (*f*), and take the cube root of the sum. (*h*) Add together the quantities obtained by rules (*b*) and (*c*), subtract the quantity obtained by rule (*f*), and take the cube root of the difference. (*i*) Add together the quantities obtained by rules (*a*), (*g*), and (*h*). The sum will be the diameter required.

*Example:* It is required to find the necessary diameter of a balloon, the following data being given:

The weight of the car and contents is 475 lbs., of the valve 25 lbs., and the air is to exert a lifting force of 100 lbs. The gas in the balloon is to be such that the difference between its weight and that of a cubic foot of air shall be 0.04 lb. The weight of the material and netting is to be 0.12 lb. per square foot of balloon-surface.

Pursuing the same steps as indicated in the preceding rules, we find: 1. The buoyant effort $= 0.04$ lb. 2. The weight $= 475 + 25 + 100 = 600$ lbs. 3. The superficial weight $= 0.12$ lb. (*a*) $2 \times 0.12 \div 0.04 = 6$. (*b*) $8 \times 0.001728 \div 0.000064 = 216$. (*c*) $0.95493 \times 600 \div 0.04 = 14{,}324$. (*d*) $15.27888 \times 0.001728 \div 0.00000256 = 6{,}187{,}946$. (*e*) $0.91188 \times 360{,}000 \div 0.0016 = 205{,}173{,}000$. (*f*) $\sqrt{(205{,}173{,}000 + 6{,}187{,}946)} = 14{,}538$. (*g*) $\sqrt[3]{(216 + 14{,}324 + 14{,}538)} = 30.75$. (*h*) $\sqrt[3]{(216 + 14{,}324 - 14{,}538)} = 1.26$. (*i*) $6 + 30.75 + 1.26 = 38.01$ feet, required diameter.

As there are many who like to know the reasons for a result, we have added the method by which the rules are obtained, which can readily be verified by those who are familiar with algebra. Let $b$ = buoyant effort, W = weight, and $a$ = superficial weight.

The balloon is to have sufficient volume that the upward pressure of the air, which is the volume of the balloon multiplied by the buoyant effort, shall be equal to the weight, increased by the product of the superficial weight and the surface of the balloon. Assuming that the balloon is in the form of a sphere, this condition is expressed by the following equation, calling $x$ the diameter of the balloon:

$0.5236 \times b \times x^3 = W + 3.1416 \times a \times x^2$. From which we deduce:

$$x = \frac{2a}{b} + \left[\frac{8a^3}{b^3} + \frac{0.95493\,W}{b} + \left(\frac{15.27888\,a^3 W}{b^4} + \frac{0.91188\,W^2}{b^2}\right)^{\frac{1}{2}}\right]^{\frac{1}{3}} + \left[\frac{8a^3}{b^3} + \frac{0.95493\,W}{b} - \left(\frac{15.2788\,a^3 W}{b^4} + \frac{0.91188\,W^2}{b^2}\right)^{\frac{1}{2}}\right]^{\frac{1}{3}}$$

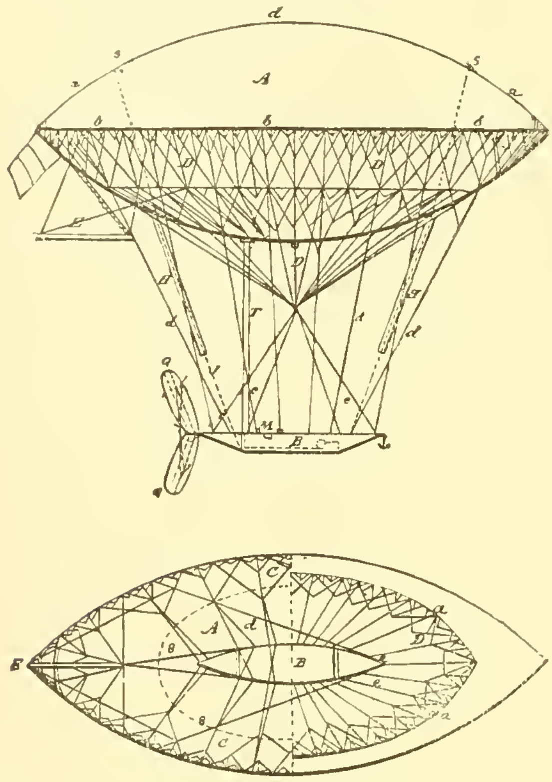
the same value as was given in the foregoing rules.

It will be evident, by inspecting the equation of condition, that the same method can be applied to any form of balloon whose volume and surface can be expressed algebraically.

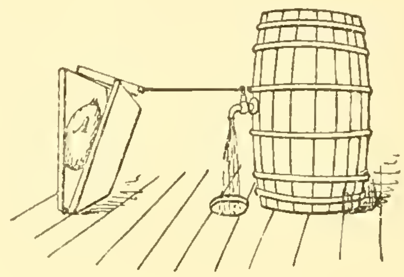
In Fig. 163 is represented M. Dupuy de Lômes's great balloon, remarkable alike for its peculiar construction and from the fact that it has been found possible to cause it to move slowly in a desired direction by means of the screw-propeller. The balloon consists of white silk taffeta lined with India-rubber, and again with nainsook. To the last a varnish is applied.

In order that the plane of the movement shall be more directly under the control of the aëronaut, the following dimensions have been adopted: Length, 118 feet 6 inches; diameter at centre, 48 feet 8 inches; area through the centre, 1,862 square feet; volume, 121,983 cubic feet; height from top of balloon to keel of car, $95\frac{1}{2}$ feet; distance between screw-shaft and major axis of balloon, 67.1 feet. The rudder is a triangular sail of $161\frac{1}{2}$ square feet area, and is manipulated by cords from the car. In Fig. 163, *A* is the balloon; *B* the car, with *D* network; *a a*, taffeta covering; *b b*, collar attaching the upper netting to the covering of the balloon; *d d*, silken ropes suspending the car; *e e*, balance-

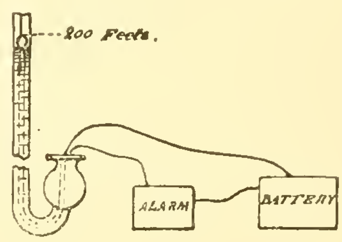
163.



164.



165.




ropes for the car; 8, small internal balloon, with line of intersection with the balloon; *E*, gaff-sail or rudder; *H*, pendent tubes for securing a constant degree of inflation. These are filled with hydrogen, which gas alone is used in the balloon, and hung down for a distance of 25 feet. As the gas expands it forces itself down these tubes, while its own pressure in the tube reacts upon the main body of the gas in the balloon, preserving such an excess of interior pressure as prevents the shape of the outer covering being altered by the wind. The small internal balloon 8, or *ballonet*, still further serves to maintain a constant surface. As the gas escapes through diminution of pressure in the primary balloon, it becomes filled with air. At *J* are the cords regulating the valves *S*; *T* is the tube for filling the *ballonet* with air; *M* is a crank for working the screw *Q*; *l* are stays for strengthening the screw. Experiment with this air-ship has given results in remarkable accordance with the inventor's calculations. Eight men, rotating the screw at 25 revolutions per minute, caused the aërostat to travel at the rate of 52.5 feet per second. This speed was augmented to 55.8 feet per second with 27.5 rotations. The *ballonet* was found to maintain the exterior surface; no rocking motion was imparted by persons in the car, and it was reported that the head of the aërostat was readily kept in any desired direction at an angle to the wind, by the labor of 8 men upon the screw-crank.

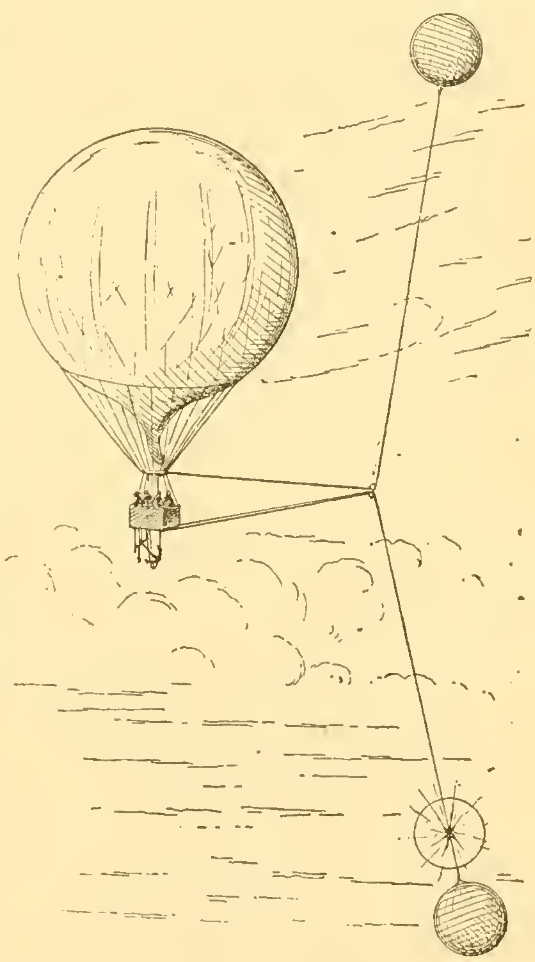
It having been shown, by the experiments of M. Paul Bert and others, that animal life may be extinguished in a too rarefied atmosphere, on account of the insufficient supply of oxygen, attempts have been made to reach exceedingly high altitudes by carrying a supply of oxygen gas, which the aëronauts inhaled when the atmosphere became unbearable. The last effort in this direction was that of MM. Sivel, Spinelli, and Tissandier, in 1875. At 23,000 feet the aëronauts, despite the oxygen, relapsed into a kind of stupor, and it is supposed that, in partial delirium, one of them cut away the oxygen-bags, with other objects, in his intense desire to mount upward. MM. Spinelli and Sivel were suffocated, and the third revived from his insensibility after the balloon had sunk to a lower altitude. The maximum height attained, shown by the barometers, was 27,500 feet. Previously, and without the aid of oxygen, Coxwell and Glaisher reached an altitude estimated at 37,000 feet.

Two automatic devices for adjusting the elevation of a balloon, and for giving warning of a descent, are illustrated in Figs. 164 and 165. The ballast-regulator, Fig. 164, is a bladder *A* inflated with air before ascending, and placed between two boards, one of which is fixed upright and the other hinged thereto. A rubber spring keeps the movable piece up against the bladder, and by suitable connection the moving-board is attached to the handle of a water-barrel, so as to turn a stream on or off in accordance with its motion. When the bladder swells, as the balloon rises into an atmosphere of

greater tenuity, the handle of the spigot is moved so as to diminish gradually or check the escape of water; while the descent of the balloon causes the contraction of the bladder and the opening of the spigot. This device was intended to relieve the aëronaut from the necessity of watchfulness during a brief period, so that he might sleep. The second apparatus, Fig. 165, is an ordinary barometer-tube, into which are led wires from a battery. The ends of the wires are connected by an insulated substance, and are adjusted at any desired mark on the barometer corresponding to a given altitude, and above the mercury. Should the balloon descend, the mercury rises, touches the wires, establishes the electric circuit, and a bell is sounded. Mr. Donaldson, the inventor of these devices, also succeeded in directing the course of his balloon, in some measure, by large kites lowered into currents of air of favorable direction. He also found that low-flying balloons were preferable to balloons at high elevations for purposes of traveling. By so adjusting his ballast that his air-ship floated at about four feet above the ground, he was able to impel himself by a pole, and by vigorous pushes on the same to cause his balloon to leap over low houses, trees, etc.

In Fig. 166 are represented Sivel's sounding balloons, for recognizing the presence of currents of air above or below the main aërostat. A rod 30 feet in length was projected from the car, and held in equilibrium by the upper balloon, which was 19 feet in diameter, and which was filled with gas. This was attached to a rope 3,000 feet long, and allowed to ascend that distance above the car. The other small balloon was filled with air, and, being attached to a line of similar length, fell far below. After many experiments and no small amount of costly investigation, the Aëronautical Society of Great Britain, so long presided over by the Duke of Argyll, has pronounced decisively against the balloon as incapable of being made useful for the purpose of locomotion, except in the way of waftage; and in a report (1876), the secretary of the Society declares that the sole improvement of which the balloon is capable is the invention of some means to secure its ascent and descent without the expenditure of gas or ballast.

166.



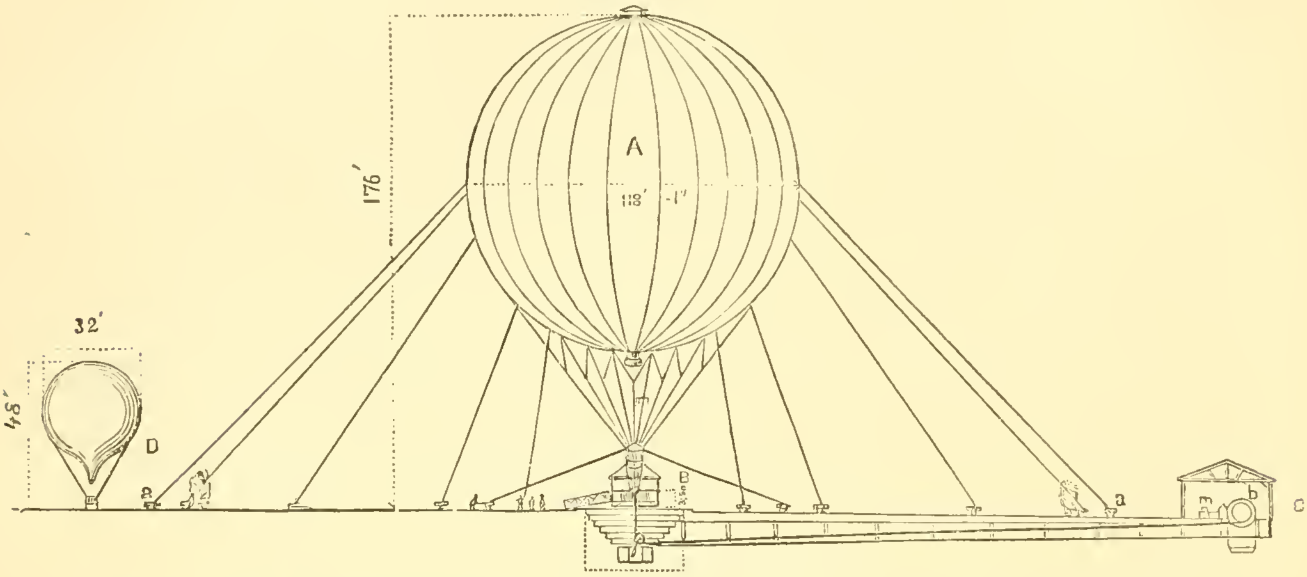
Suppose we have, for example, a balloon so weighted that it would float on the discharge of 35 lbs. of ballast, or on receiving an additional thousand cubic feet of gas. It is plain that, if some mechanical means (say a screw acting vertically) were added, capable of exerting a lifting force of 35 lbs. more than its own weight—a light 2-horse-power engine would drive it—the voyager would be able to rise without discharging ballast, or sink without discharging gas, and so be able to avoid obstacles while drifting over the surface, or to rise above adverse currents to such as might be more favorable.

But, for the purposes of real aërial navigation, such drifting is wholly inadequate. The work to be accomplished is not the floating of a relatively light body in more or less favorable air-currents, but the propulsion of a heavy body with a force sufficient to overcome all aërial resistance, and with velocity enough to make the inevitable driftage relatively unimportant. This has not yet been achieved, though the efforts toward it have shown some very encouraging results. Certain experiments made at the expense of the Aëronautical Society, to determine the exact lifting pressure of air-currents against a plane inclined at different angles, obtained results which are especially promising. The plane used was a steel plate a foot square, and the substitute for wind or the resistance, occasioned by the passage of a body at high speed through the air, was the blast of a powerful fan-blower. Placed at right angles to this blast, the pressure on the plate was $3\frac{1}{4}$ lbs., indicating a wind-velocity of about 25 miles an hour. Inclined at an angle of 15°, the plate received a direct pressure of only one-third of a pound, while the lifting pressure amounted to $1\frac{1}{3}$ lb. In other words, a plane of 1 square foot, held at an angle of 15° against a current of air having the velocity of 25 miles an hour, will carry four times as much weight as it meets resistance. A less angle than 15° could not be tried, owing to some obstruction to the action of the apparatus. The experiments showed, however, that the ratio of the lift to the thrust greatly increased as the inclination of the plane diminished, and also that the lifting power of the current, per square foot of plane, increased with the extension of the sustaining surface, probably on the same principle that makes a large sail on a ship so much more efficient than an equal area of small sails.

Regarding the power required to lift a weight in the air by means of vertical screws, in a "Report on the English Aëronautical Exhibition of 1868," by Mr. Wenham, the following paragraph appears: "The Society has brought out the remarkable fact that a 1-horse-power engine can be made to weigh only 13 lbs., thus showing the possibility of obtaining flight by the repudiated system of vertical screws, even with the enormous expenditure of power that this plan is known to require." In

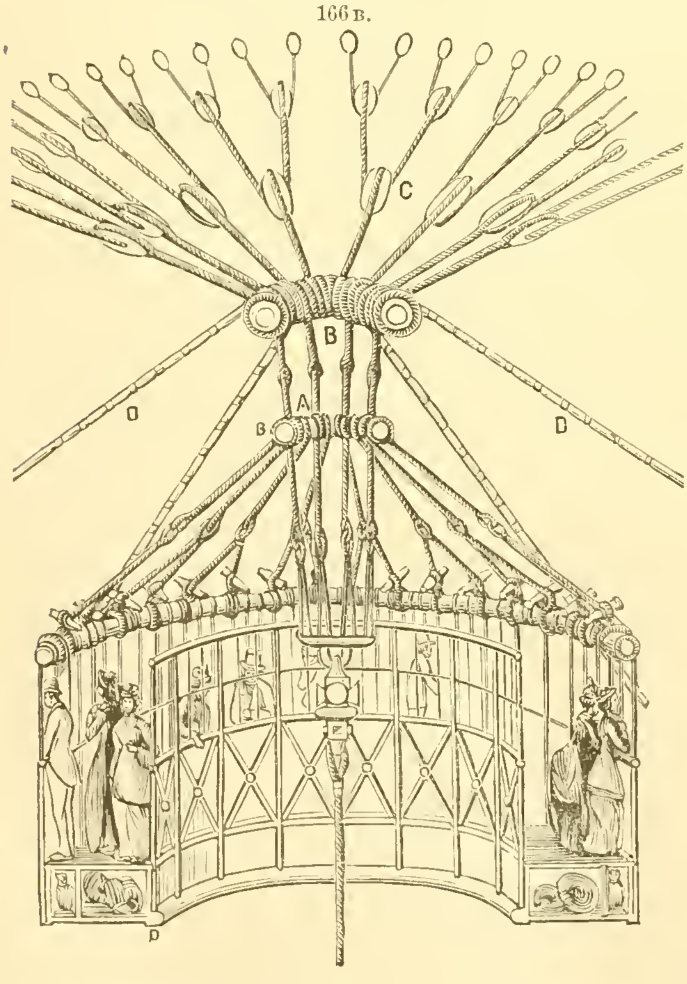
order to ascertain what actual lifting power could be obtained with planes moving in horizontal orbits, Mr. Moy constructed new aëro-plane wheels, 12 feet in diameter, with 12 planes to each wheel, the whole presenting 160 square feet of surface, driven by a steam-engine weighing 80 lbs. By placing the whole acting surface on these two wheels, an interesting experiment was carried out. It was palpable, however, that, from the conditions of the actual trial, the full lifting power due to

166 A.




the surface, angle, and velocity could not be hoped for. These revolving planes were traveling all the time in one circle. They had not the advantage of obtaining an abutment upon a previously undisturbed body of air. The experiment was in an inclosed part of the building. A great part of its power was expended in drawing downward a body of air. The whole weight of the machine was 186 lbs. Levers were attached to the spindle of the aëro-plane wheels, which were weighted to take off all over 120 lbs. This latter weight was raised from the floor as much as 6 inches under one aëro-plane and 2 inches under the other, this inequality being due to one wing-plane having broken.

166 B.




The engine, therefore, was proved capable of raising itself, and 40 lbs. additional weight, under great disadvantages. The revolutions of these two 12-feet aëro-planes were 67 per minute.

The largest and probably the most perfect balloon which has been made is that designed by M. Henri Giffard, and exhibited by him in the City of Paris during the continuance of the French International Exposition of 1878. The following is a summary of some of the principal figures connected with this interesting aërostat: —Dimensions: Diameter of the spherical envelope, 118 feet 1 inch; height above the ground when at its moorings, 180 feet 5 inches; capacity of envelope, 882,915 cubic feet. Weights: Material of the balloon with its two valves, 5 tons 3 cwt.; netting, 3 tons 5 cwt.; ropes attached to the nets, rings, pulleys, etc., 3 tons 12 cwt.; car and its appurtenances, 1 ton 11 cwt.; total weight of materials, 13 tons 11 cwt. Weight of cable supported by the balloon, 2 tons 9 cwt.; fifty passengers and two aëronauts, 3 tons; ballast, grapnels, etc., 3 tons; total weight lifted, 22 tons.

The shape of this balloon, Fig. 166 A, is perfectly spherical, the object of thus departing from the usual pear-shaped form being to obtain a greater capacity with the same weight of material, and hence greater lifting power. The sphere is constructed of 104 gores, each measuring 3 feet 6 inches at its widest part. The material is a compound fabric composed of layers: 1, muslin; 2, pure India-rubber; 3, linen canvas; 4, pure India-rubber; 5, canvas; 6, vulcanized rubber; 7, muslin. The surface

is covered with a mixture of boiled linseed-oil and litharge, and afterward with a coat of white paint. The method of making the seams is as follows: The edges of two gores having been sewn together by two undulating lines of stitches, a strip of material consisting of a thickness of vulcanized India-rubber between two layers of muslin is laid over the outside of the seam, being made to adhere by a coat of India-rubber varnish previously applied; and the inside of the seam is covered in the same way with a strip of muslin saturated with the same solution of India-rubber. No knots are used in the netting, seizings being applied at the intersection of the ropes, and the junctions covered with goat-leather. The car, Fig. 166 B, is suspended by 16 cords from a strong steel ring *A*, of small diameter, and this ring is in its turn suspended at a distance of about 4 feet from a second and larger ring *B*, which is hollow, and is constructed of steel plates having an external diameter of 5 feet 3 inches. The upper ring is attached by 16 ropes to as many sheave-blocks *C*. Through each of these blocks passes a smaller rope carrying a smaller block at each end. Consequently, there are 64 of these latter blocks supporting the weight of the car, and communicating the lifting strain of the balloon to the cable by which it is attached to the ground. At *D* are the moving ropes. The valve consists of a metallic disk $21\frac{1}{2}$ inches in diameter, which is maintained in close contact with a seat of vulcanized rubber by a series of spiral springs fixed above it. It is arranged in the centre of a large circle of a similar material to that of which the balloon is constructed, but somewhat thicker, and is held between two flanges of wood 8 feet in diameter, which are held together by screws. In and closing the neck of the balloon is a second valve, which consists of a circular metallic plate $31\frac{1}{2}$ inches in diameter, which is kept pressed against its seat by a set of very delicate springs, so that upon the slightest increase of pressure within the balloon the valve opens, and a quantity of gas proportional to the excess escapes. The car consists of an ornamental annular balcony, 19 feet 8 inches in external diameter, the floor being 3 feet 3 inches wide.

In Fig. 166 A is given an elevation of M. Giffard's balloon, showing it as arranged in the court of the Tuileries, Paris. *A* is the balloon; *B*, the car suspended over the conical pit with the embarking bridge in position. At *C* is the winding machinery to which the retaining cable of the balloon is brought. This cable is nearly 3,000 feet long, weighs over $2\frac{1}{2}$ tons, and is tapered from a diameter of 3.35 inches at its upper end to 2.56 inches at its lower extremity. At its point of connection with the aërostat the cable is secured to a dynamometer, by which the strain on the cable and the lifting power of the balloon are determined. The small balloon marked *D* represents an ordinary aërostat of 35,000 cubic feet capacity, capable of carrying 3 or 4 persons. (See *Engineering*, xxvi., 658.)

Mr. C. F. Ritchel has devised an aërial machine wherein is employed a balloon 25 feet in length and 13 in diameter, weighing 66 lbs., and charged with hydrogen gas. Broad worsted bands extend over that and down to a rod of brass tubing, from which the machine is suspended by slender cords. The after portion of the machine is at the base a parallelogram of rods, from which rise, lengthwise, curved rods, drawn near together at the top. All these rods are of mandrel-drawn brass, light and very strong. Above the apex of this form rises a cog-edged steel wheel, with double handles so geared to a four-bladed fan moving horizontally directly beneath, that the operator can give the fan 2,000 revolutions per minute. The extreme diameter of this revolving fan is 24 inches. The blades are set like those of the screw of a propeller. Just behind the wheel is a very small seat, upon which the operator perches. His feet rest upon two light treadles above and in front of the fan. From the front of this form spring other rods, carrying at their extremity a vertically-working revolving fan, 22 inches in diameter. It is so geared to the main fan that it may be operated or not, at the pleasure of the driver, and can be made to turn from one side to the other, so as to deflect the course of the machine in the air. This fan makes 2,800 revolutions per minute when the other is making 2,000. The total weight of the apparatus is 114 lbs. For particulars of trial of this machine, which seemingly worked quite satisfactorily in still air, see *Scientific American*, xxxviii., 405.

The Flying Machine.—Human muscular power being proportionately very much inferior to that of the bird, it follows that no contrivance of the nature of wings can be successfully operated by the unaided strength of a man's muscles. Either some motor must be employed to drive the lifting mechanism, or an auxiliary balloon, as already pointed out, must be used. In view of the fact that a kite is sustained in the air by the pressure of the wind against it, provided the direction of the wind is oblique to its surface, some authorities consider the moving plane to be the simplest mechanism that can be devised for the flying-machine, in connection with two propeller-wheels, turning in opposite directions, so as to keep the machine in an upright position. The best angle of inclination of the fixed plane—that is, the angle in which the least amount of surface is required—is 54° 10′ with a horizontal line; but the power required for motion in this case is very great. By reducing the angle between the fixed surface and a horizontal line, the power required for propulsion is diminished; but it is necessary to give the machine a much higher velocity, in order that it may be sustained in the air; or, if the original velocity is retained, the area of fixed surface must be largely increased, which will, of course, add to the weight. It must be remembered also that the machine will not be sustained unless it is in motion, so that it cannot rise from the ground, but must be launched from an elevation. M. Bruignac considers that, by attaching balloons to flying-machines, they can be propelled by the aid of less power than in the case where a sustaining plane surface is used. The best form of balloon, according to M. Bruignac, is that of a horizontal cylinder with conical ends, the slant height of the cones being equal to the diameters of their bases. It is found by experiment that, if three bodies having the same cross-section are moved through the air at the same velocity, having the forms respectively of a circular plane, a sphere, a cone with slant height equal to diameter of bases, the resistances to motion in the two latter cases will be (calling the resistance of the plane R) for the sphere $\frac{R}{2}$, and for the cone $\frac{R}{3}$.

The most favorable form of aërial machine, according to M. Bruignac, is a combination of a balloon

with a sustaining plane. By his calculations, it appears that the most advantageous design, for a speed of 20 miles an hour in a calm, must not weigh, with engines, navigators, fuel, stores, etc., more than 2,200 lbs., and must have the following dimensions: There must be a balloon, filled with hydrogen, 22 feet in diameter and 94 feet long, together with a sustaining plane 94 feet long and 16 feet wide; and an engine capable of exerting from 6 to 7 horse power. This is equivalent to saying that the problem is impossible with our present means of construction, and would seem to settle the matter conclusively, unless it can be shown that a more favorable plan than the best one discussed by M. Bruignac can be designed. It is pretty evident that, if a machine is not practicable even in theory, there is little hope of its actual success.

Dr. F. A. P. Barnard has published a paper, entitled "Aërial Navigation" (1875), in which M. Bruignac's investigations are reviewed. Dr. Barnard offers the following suggestion: "If it is possible to lift a given weight into the air and make it move in any desired direction, it is certainly easier to do the same with a part of that weight. Let the inventor, then, attach his lifting apparatus to some vehicle on land—as, for instance, a railroad-train—and, by sustaining some of the weight, make it move more easily; let him remove the locomotive, and put in its place his aërial propeller. If this works well, there is some hope of actually getting into the air; but should it fail, it would seem advisable for him to abandon his experiments."

The reader is referred to the "Patent-Office Reports of the United States" for descriptions of hundreds of devices whereby it has been hoped to solve the problem of aërial navigation. The quest has a singular fascination, but it has ruined thousands, and teems with examples of misdirected energy and genius. In conclusion, it may be added that the problems to be solved before aërial navigation takes its place among human achievements are consequently these two: the invention of an apparatus to accomplish the work of the bird's wings and tail, and an engine capable of developing great power with comparatively little weight of machinery and fuel. For the purpose of navigation, the flying-ship must be, however, like the bird, heavy in comparison with air, that it may not be at the mercy of every gust of wind; and it must be strong enough to withstand the pressure of strong gales, or, what is equivalent, the resistance due to rapid motion. Hence it is evident that, whatever it may be, the successful air-ship will not be and will not contain a gas-bag. For the practical navigation of the air, the balloon is and will ever be a delusion and a snare; and the general recognition of this truth by intelligent workers in this field is one of the most encouraging features of modern aëronautics.

It is quite possible that aërial rafts, supported by balloons, may sometimes be useful in regions favored with winds which blow steadily in a fixed direction for months at a time; but in ordinary climates they cannot but be as useless for commercial purposes as log-rafts in a sea everywhere as vexed by conflicting currents as Hell Gate was in its worst days. A self-propelling vessel supported by a balloon would be little, if any, better. No balloon light enough to sustain such a vessel could begin to withstand the pressure it would meet in stemming or crossing the current of a moderate wind, or in being driven through still air at the rate of 20 or 30 miles an hour; and unless it can do this, and much more, it is out of the question for practical navigation.

*Works of Reference.*—A very large and complete list of works on aëronautics will be found in "Aërial Navigation," a fragmentary volume written by Charles B. Mansfield in 1851, and published in London and New York in 1877. The rules and theoretical discussion in this article are by Mr. R. H. Buel, in *Scientific American*, vol. xxii., 64. See also vol. xxix. of same journal.

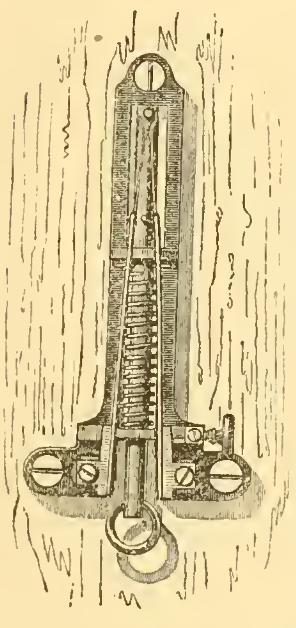
AJUTAGE. A tube fitted to the mouth of a vessel for the purpose of modifying the discharge of water. If cylindrical or conical, it considerably increases the efflux of water. In the former case, when the length of the ajutage does not exceed four times its diameter, the increase is in the proportion of 1.33 to 1. With an ajutage composed of two conic frustrums on a horizontal axis, the bases opening respectively into the vessel and into the atmosphere, the length of the outer frustrum being three times that of the inner one, and the opening into the vessel being seven-eighths the size of the delivery-opening, the proportion of 3 to 2 has been obtained.

ALARMS. Machines for giving warning of danger or calling attention. For boiler-alarms, for indicating low water or an over-high pressure of steam in steam-generators, see BOILERS. For marine-alarms, including fog-whistles, etc., see LIGHTHOUSE and BUOYS.

*Fire-Alarms*, as a rule, depend for their operation upon the increased temperature of the air in the vicinity of the fire, or upon the burning away of certain connecting-cords which are stretched in exposed situations. Of the first of these, the simplest form is a gun loaded with blank cartridge and suspended near the ceiling. The increased heat determines the explosion. Of the second, a simple arrangement is a weight hung by a cord. When the cord burns, the weight falls, the crash giving the alarm. Another device consists of a series of tubes which proceed from each floor to a central office. The occurrence of fire in the edifice produces a blast of air (due to its expansion) from the tubes. In another invention the increased heat of the apartment causes expansion of a body of mercury, and brings it in contact with a wire of a metal which readily amalgamates. The wire then breaks with the strain, and releases a clock-work, which sounds a bell and opens a cock, allowing the escape of an extinguishing agent. Another device involves a thermostatic arrangement, by which a closing of an electric circuit is made when the metal expands with the heat. The thermostat is a column of mercury which ascends in a tube and makes the electric connection, or a plate or coil of two metals on the principle of the chronometer-balance, or it is an elongating-rod. The connection made, an armature in the telegraphic wire circuit is attracted by its magnet, and releases a clock-work alarm. The Tunnicliffe alarm is a small cylindrical metal barrel, attached by a screw to any part of the room. It is loaded with a small charge of powder, and provided with a fuse containing a chemical mixture, which ignites whenever the surrounding atmosphere is heated to 200° Fahr. The explosion follows, making a loud noise, and, if desired, a small plug is ejected so as to strike and release a detent in a clock-work, which sounds a bell. Fig. 167 represents a fire-alarm

which, when acted upon by heat, causes a bell to ring, and which may be ordinarily employed in lieu of the common press-button as a means of sounding electric bells for calls. To the two metal columns to which the battery-wires are fastened are attached two thin elastic plates of metal tipped with steel. Their tendency, when heated, is to curve inward, come in contact, and establish electric communication, thus sounding a gong elsewhere situated. Between the plates is a rod supported by a spring. When the rod is pulled down, a metal part on its end touches both plates, and the current passes. The plates, when the rod is held up by its spring, are separated by a piece of insulating material on the rod. This device is very sensitive, and may be adjusted by moving one of the plates by the screw shown on the side.

167.



*Earthquake-Alarms* have been made, based on the supposition or discovery that a few seconds previous to an earthquake the magnet temporarily loses its power. To an armature is attached a weight, so that, upon the magnet becoming paralyzed, the weight drops, and, striking a bell, gives the alarm.

*Gas-Alarms* are employed to give warning of fire-damps in mines, and also of dangerous leakage of illuminating gas. Chuard's device consists of a light metallic stem, surmounted by a thin glass globe filled with atmospheric air. On the lower end of the stem is a ball which gives the device buoyancy, and also a weight, so that the apparatus is maintained in vertical position in a vessel of distilled water. The weight is graduated so that the normal condition of the air causes the finger to indicate zero on the scale. When the surrounding air becomes mixed with hydrogen, the relative weight of the glass globe is changed, and, its contained air being heavier than the surrounding atmosphere, it sinks, and thus moves a pointer on a scale. At a certain point on the latter is a mark indicating that the mingled air and gas has become dangerously explosive, and when the pointer reaches this mark it comes in contact with a magnet, by which a lever is moved and an alarm sounded. Several other devices founded upon endosmotic action have been proposed. A bladder of air is placed in a position exposed to the action of escaping hydrogen, and, by the absorption of gas, its form or specific weight becomes changed, and by this means a mechanical device for sounding an alarm is actuated. Another gas-alarm for mines or rooms consists of a galvanic battery with a bell, and a glass tube filled with chloride of palladium. This metallic salt is extremely sensitive to the presence of carbonic-acid gas, a small quantity of which at once throws down some of the metal from the solution, and this precipitate, collecting in the bottom of a tube, at once establishes a connection in a current of electricity, and an electric bell is sounded.

*Ansell's Fire-Damp Alarm* consists of a small tube bent in the form of a U, one of the branches of which ends in a funnel closed by porous earthenware. The tube contains mercury, and, in ordinary circumstances, when the apparatus, full of air, is placed in pure air, the surfaces of mercury in the two branches are on the same level. But this is not the case when the air is vitiated by proto-carbonate of hydrogen. This gas will filter through the earthen partition, penetrate into the funnel, increase the pressure, and make the column of mercury rise in one branch of the bent tube so as to cause a contact between two platinum wires which terminate in the two poles of an electric battery. The current is thus established, and, if an electric bell is placed in the circuit, a signal will be given, which can be conveyed to any distance.

*Mill-Hopper Alarms* are attachments to grinding-mills to indicate that the hopper is nearly empty of grist. Mills have been burned by sparks and heat generated by the stones when running empty; and there are numerous devices for giving timely notice of the fact, and also for stopping the machinery thereupon. In one apparatus of this kind, which may serve as an example, a bell is so arranged within the hopper that, when surrounded by the grain, it is held stationary, but when uncovered is caused to ring by the tremulous motion of the hopper. The grain rests upon a float hinged near the bottom of the hopper. When the grain is about expended, the float is raised by a weighted lever, and the spout of an upper hopper is opened to supply the lower one with grain.

*Money-Drawer Alarms* are devices which strike a bell when the till-drawer is opened. A cleat on the lower portion of the drawer engages a latch, and rings the bell when the drawer is opened or closed.

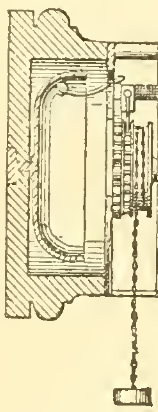
*A Pocket-Alarm* is shaped like a watch, and has a chain attached to the hook at its upper end. In case a pickpocket attempts to take the chain, his pulling on the same turns a spring-wheel and moves a hammer in the apparatus which sounds a bell. Another device is designed to be attached to the watch, and also to the chain. On the latter being jerked, a spring hammer inside the apparatus is freed, and a percussion-cap is struck and exploded.

*Clock-Alarms* usually consist of a bell or wire coil and hammer, which is set in motion by a recoil escapement. Devices are provided so that whatever figure on a small movable dial is made to come to a small pointer set as a tail to the hour-hand, the alarm is let off at that hour, and operates until the spring which actuates it runs down. Alarms are also arranged in connection with the mechanism of watches, to sound at certain fixed times.

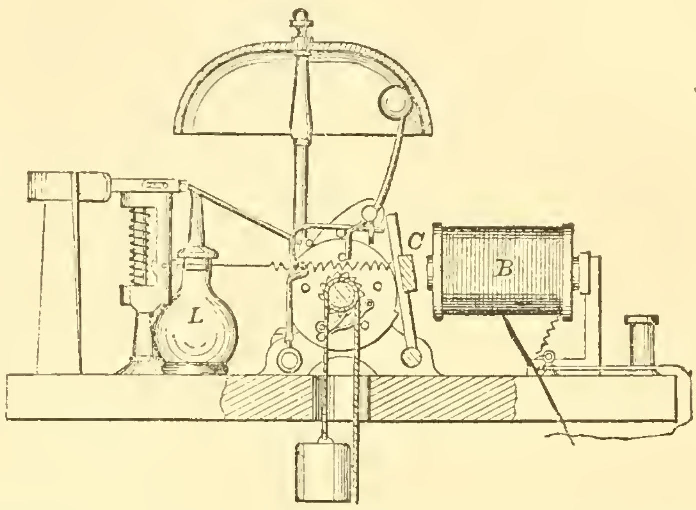
*Bilge-Water Alarms* are used on ships to indicate an excessive depth of water in the hold, and a possible leak. One form has a rectangular box, placed vertically near the bottom of the vessel. As the water rises in the box a float therein is lifted, and the rod of the latter connects with clock-work, so that the same may be released and allowed to sound a bell when the float reaches a certain height. A dial is provided in connection with the rod, so as to indicate the height of the float at all times. In another form a tube is bent to conform to the transverse sectional shape of the vessel, and is pro-

vided with a whistle at each end. At the lowest midship portion the bilge-water is admitted at a gauze-covered opening. When a considerable amount of water has collected in the pipe, the rolling of the vessel causes the water to expel the air in the tube through the whistles, which thus sound an alarm. A form of leak-alarm is represented in Fig. 168. The water rising in the hold elevates the float, permitting the spring-drum to revolve and wind up the chain. This rings the alarm-bell, and

168.



169.



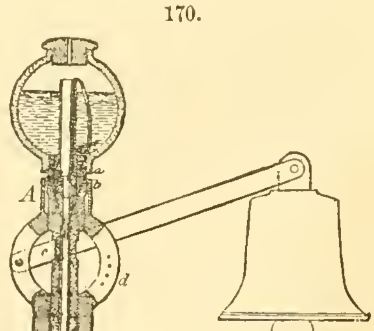

moves the index, which signifies the depth. As the water falls the float rewinds the spring. An iceberg-alarm is a thermometrical device.

*Burglar-Alarms* are devices to be attached or connected with doors or windows, so as to give warning of the attempted entrance of an intruder. Fig. 169 shows one of the numerous forms of the application of the electric circuit and apparatus to the above purpose. Copper wires running through the house connect with a battery, and have circuit connections attached to the doors or windows, so that, when one of the latter is opened, the armature is released from the magnets and causes a bell to strike, and also ignites a fluid-lamp or candle, or turns on the gas, left burning low. The circuit being completed by the motion of the door or window, the magnet *B* attracts the armature *C*, and sets free a detent, so that a weight runs an alarm-hammer, while the match-puller reciprocates and lights the lamp or gas. Portable burglar-alarms are constructed in the form of wedge-shaped cases having clock-work and a gong inside. These are placed on the floor, so that the door of a room, on being opened, strikes the device and moves a detent, which allows the clock-work to run down and sound the bell.

*Alarm-Funnels* are used to indicate that liquid in a barrel has risen to a certain point. The funnel being placed over the bung-hole of the barrel, the rising liquid raises the float, which detaches the button from its stop and rings the alarm-bell.

A *Hot-Bearing Alarm*, for giving warning of an overheated journal, is illustrated in Fig. 170. It is the invention of Mr. S. Alley. The alarm is given by a tappet fixed to the revolving-shaft striking against the clapper of a bell. This bell, as will be seen from the engraving, Fig. 170, is hung from the end of a lever which is supported in a raised position by resting on a knife-edge formed at the side of a hollow spindle which rests on the top of a hollow fusible plug *A*, inserted in a casting which can be screwed into the top of the bearing. The plug *A* is made of hard lubricant, and, on its melting, the hollow plunger on the spindle *c* falls, thus lowering the bell so that its clapper is acted upon by a wooden striker fixed to the revolving-shaft. When the plunger *c* falls the glass globe containing oil falls with it, until the collar *a* of its mounting comes into contact with the tubular part *b* of the main casting. This arrests the further fall of the globe, and the plunger *c*, continuing to fall, parts the conical joint shown, and allows any oil that may be in the glass globe to fall at once through the holes *d* on to the bearing.

170.




ALCARAZA. A vessel of porous earthenware, used for cooling the contained liquid by evaporation from the exterior surface—popularly called a "water-monkey." The vessel is usually enveloped in a light cord net, and, after being filled, is suspended in a draught of air.

ALLOYS. *Antimony Alloys.*—All the antimony-metal of commerce may be considered an alloy. It is never pure, but contains iron in all instances. Antimony and tin, in equal parts, form a moderately-hard, brittle, but very brilliant alloy, not soon tarnished, and frequently employed for small speculums in telescopes. Of all the metals, antimony combines most readily with potassium and sodium. These alloys are obtained by smelting the carbonaceous compounds of these metals or their oxides mixed with carbon. The presence of other metals, such as copper and silver, does not diminish the affinity of these metals for antimony. The alloy thus formed of the alkaline metals is not easily evaporated by a strong heat. 80 parts of lead and 20 of antimony form type-metal; to this, commonly, 5 or 6 parts of bismuth are added. Tin 80 parts, antimony 20, is music-metal; it is also composed of 62.8 tin, 8 antimony, 26 copper, and 3.2 iron. Plate-pew-

ter also contains from 5 to 7 per cent. of antimony; 89 tin, 7 antimony, 2 copper, 2 iron, is one of these compositions. Britannia-metal contains frequently an equal amount of antimony. Queen's-metal is 75 tin, 8 antimony, 8 bismuth, and 9 lead. Crude antimony is employed for purifying gold.

*Aluminum Alloys.*—The only aluminum alloys which have acquired importance in the arts are the so-called aluminum bronzes. According to M. Morin, very homogeneous alloys are obtained with copper, and 5, 7½, and 10 per cent. of aluminum. The alloys with 5 and 10 per cent. of aluminum are both of a golden color, while that with 7½ per cent. has a greenish tint. Even so small an addition as 1 per cent. of aluminum to copper considerably increases its ductility and fusibility, and imparts to it the property of completely filling the mould, making a dense casting free from all air-bubbles. At the same time the copper becomes more resistant of chemical reagents, increases in hardness without losing in malleability, and unites in itself the most valuable qualities of bronze and brass. A copper alloy with 2 per cent. of aluminum is said to be used in the studio of Christofle, in Paris, for works of art. It works well under the chisel and graver.

The true aluminum bronzes are alloys containing 90 to 95 per cent. of copper with 10 to 5 per cent. of aluminum. The direct mixture, by first fusion, of 10 parts of aluminum and 90 of copper, gives a brittle alloy, which, however, increases in strength and tenacity by several successive fusions effected in crucibles. The aluminum bronze is homogeneous, and possesses sufficient expansion to fill the remotest parts of the mould. It affords sharp castings that can be worked more readily than steel. Aluminum bronze may be forged at a dull-red heat, and hammered until cooled off without presenting any flaws or cracks. Like copper, it is rendered milder and more ductile by being plunged into cold water when hot. The bronze polishes beautifully and possesses great strength—according to Anderson's experiments, an average of 75,618½ lbs. per square inch. The resistance to compression is feeble. From the experiments of Colonel Strange on the relative rigidity of brass, ordinary, and aluminum bronze, it appears that the last named is 40 times as rigid as brass, and 3 times as rigid as ordinary bronze.

Other experiments have shown that aluminum bronze does not expand or contract as much as ordinary bronze, or brass; that under the tool it produces long and resisting chips, does not clog the file, engraves nicely, etc., and it is easily rolled into sheets; that in the melted state it expands very much, and is fit for the sharpest castings; but that, as it cools off rapidly, it is subject to shrinkage, and hence to cracks when the articles are bulky, thus requiring numerous runners and a heavy feeding head; and lastly, that, although not entirely unoxidizable, it is not so readily tarnished by contact with the air as polished brass, iron, steel, etc. Dr. Biedermann speaks very highly of this metal: "In the construction of physical, geodic, and astronomical instruments," he says, "it is far preferable to all other metals. In jewelry, and articles of art and luxury, it is employed in large quantities. Many kinds of house-utensils are made of it, and it is also adapted to journal and axle boxes. Gun and pistol barrels, as well as rifled cannon, have been made of it, and have done excellent service." It has been highly recommended for type-metal—type made of it lasting, it is affirmed, fully 50 times as long as those from common metal type. It has been employed for the bed of perforating machines for perforating postage-stamps, and for the main-springs of watches (90 copper and 5 aluminum), being very hard and elastic, not magnetic, and less liable to rust than steel. Its price, however, ranging, according to its percentage of aluminum, is probably the greatest impediment to its common use.

Aluminum alloys with many other metals have been made, but none of them have acquired a permanent value in the arts. They may be passed over with the brief remark that aluminum containing 4 per cent. of silver is employed for the beams of fine balances, for which it is peculiarly fitted from its comparative lightness and stability; and that the addition of a small percentage of aluminum to steel is claimed to impart special virtues to the latter—a claim which, however, has not yet been well established.

*Arsenic Alloys.*—Arsenic promotes the union of those metals which without its assistance do not unite. It has this effect on zinc and lead, iron and lead, and iron and aluminum. Like antimony, it has a remarkable tendency to cause metals to crystallize, but its alloys are not so brittle as those of antimony. In producing a high degree of fluidity, it admits of the melting of metals at a low heat, and enables them to contract in small compass. All metals combine easily with arsenic, and the alloys, with the exception of silver, are readily decomposed by continued heat. It requires caution in operating upon the arsenic alloys of alkaline metals, as they decompose rapidly in damp air, and evolve arseniureted hydrogen, a virulent poison. Alloys of copper and arsenic are commonly known as white copper or tombac. Arsenic is added to lead in the proportion of two or three thousandths in the manufacture of shot, the effect being to help the solidification, and to cause the metal to pour more readily. The alloys of arsenic are generally known as arsenides, and are rather "unions" than true alloys of metals.

*Bismuth Alloys.*—Bismuth is scarcely used alone, but it is employed for imparting fusibility to alloys, thus:

8 bismuth, 5 lead, 3 tin, constitute Newton's fusible alloy, which melts at 212° F.

2 bismuth, 1 lead, 1 tin, Rose's fusible alloy, which melts at 201° F.

5 bismuth, 3 lead, 2 tin, when combined, melt at 199°.

8 bismuth, 5 lead, 4 tin, 1 type-metal, constitute the fusible alloy used on the Continent for producing the beautiful casts of the French medals, by the *cliché* process. The metals should be repeatedly melted, and poured into drops until they are well mixed. Mr. Charles V. Walker substituted antimony for the type-metal, and strongly recommends this latter in preference to the first-named fusible alloy. See "Electrotype Manipulation," part ii., pp. 9–11, where the *cliché* process is described.

1 bismuth and 2 tin make the alloy Mr. Cowper found to be the most suitable for rose-engine and eccentric-turned patterns, to be printed from after the manner of letter-press. He recommends the thin plates to be cast upon a cold surface of metal or stone, upon which a piece of smooth paper is

placed, and then a metal ring; the alloy should neither burr nor crumble; if proper, it turns soft and silky; when too crystalline, more tin should be added.

2 bismuth, 4 lead, 3 tin, }
1 bismuth, 1 lead, 2 tin, } constitute pewterer's soft-solders.

All these alloys must be cooled quickly, to avoid the separation of the bismuth; they are rendered more fusible by a small addition of mercury.

*Cadmium Alloys* are little used in the arts. The ready volatilization of the metal has been the chief drawback to their formation and study. 78 parts of cadmium to 22 parts mercury is sometimes used for filling teeth. 750 parts gold, 166 silver, and 84 cadmium, is an alloy for jewelers' use. Cadmium 2, tin 2, lead 1, and bismuth 3, melts at 150° F., and is known as Wood's fusible alloy.

*Chromium Alloys.*—These are usually combinations of the metal with iron or steel. Iron 68.60 and chromium 31.40 is fibrous, silvery, and very brittle. Alloys of steel and chromium can be polished and damascened. The addition of from 1 to 2 per cent. of chromium tends to harden and slightly increase the tenacity and ductility of cast-steel. Chromeisen, however, has been used to replace Spiegeleisen in steel-making, and the result has been a very soft steel. This is remarkable, owing to the known hardness of chromium. The alloy, on being analyzed, yielded metallic iron 96.40 per cent.; metallic chromium, 2.30 per cent.; lime, silica, 1.30, and carbon traces. Chromium alloys have been made with tin and copper, but have no utilizations.

*Cobalt Alloys.*—Cobalt with antimony forms an iron-gray alloy; with iron, a very hard alloy; with gold, it is yellow and fragile; with platinum, fusible. Cobalt amalgam resembles silver. Alloys of this metal have been made with lead and tin, but have no especial interest.

*Copper Alloys.*—Copper unites easily with most other metals, and forms the basis of a large number of important alloys. Of these the principal are those made of copper and zinc, or the brasses, and those of copper and tin, known as bronze, gun and bell metal.

Copper, when alloyed with nearly half its weight of lead, forms an inferior alloy, resembling gun-metal in color, but very much softer and cheaper, lead being only about one-fourth the value of tin, and used in much larger proportion. This inferior alloy is called pot-metal, and also cock-metal, because it is used for large vessels and measures, for the large taps or cocks for brewers, dyers, and distillers, and those of smaller kinds for household use.

Generally the copper is only alloyed with one of the metals—zinc, tin, or lead; occasionally with two, and sometimes with the three in various proportions. In many cases the new metals are carefully weighed, according to the qualities desired in the alloy, but random mixtures more frequently occur, from the ordinary practice of filling the crucible in great part with various pieces of old metal, of unknown proportions, and adding a certain quantity of new metal to bring it up to the color and hardness required. This is not done solely from motives of economy, but also from an impression which appears to be very generally entertained, that such mixtures are more homogeneous than those composed entirely of new metals, fused together for the first time.

The remarks we have to offer on these copper alloys will be arranged in the tabular form, in four groups; and, to make them as practical as possible, they will be stated in the terms commonly used in the brass-foundery. Thus, when the founder is asked the usual proportions of yellow brass, he will say, 6 to 8 oz. of zinc (to every pound of copper being implied). In speaking of gun-metal, he would not say it had one-ninth, or 11 per cent., of tin, but simply that it was $1\frac{1}{2}$, 2, or $2\frac{1}{2}$ oz. (of tin), as the case might be; so that the quantity and kind of the alloy, or the *addition* to the pound of copper, is usually alone named.

*Alloys of Copper and Zinc only.*—The marginal numbers denote the ounces of zinc added to every pound of copper.

$\frac{1}{8}$ to $\frac{1}{2}$ oz. Castings are seldom made of pure copper, as, under ordinary circumstances, it does not cast soundly; about half an ounce of zinc is usually added, frequently in the shape of 4 oz. of brass to every pound of copper; and by others, 4 oz. of brass are added to every 2 or 3 lbs. of copper.

1 to $1\frac{1}{4}$ oz. Gilding-metal, for common jewelry. It is made by mixing 4 parts of copper with 1 of calamine brass; or sometimes 1 lb. of copper with 6 oz. of brass. The sheet gilding-metal will be found to match pretty well in color with the cast gun-metal, which latter does not admit of being rolled; they may be therefore used together when required.

3 oz. Red sheet-brass, made at Hegermühl, or $5\frac{1}{2}$ parts copper, 1 zinc. (*Ure.*)

3 to 4 oz. Bath-metal, pinchbeck, Mannheim gold, similor, and alloys bearing various names, and resembling inferior jeweler's gold greatly alloyed with copper, are of about this proportion; some of them contain a little tin; now, however, they are scarcely used.

6 oz. Brass, that bears soldering well.

6 oz. Bristol brass is said to be of this proportion.

8 oz. Ordinary brass, the general proportion; less fit for soldering than 6 oz., it being more fusible.

8 oz. Emerson's patent brass was of this proportion, and so is, generally, the ingot brass, made by simple fusion of the two metals.

9 oz. This proportion is the one extreme of Muntz's patent sheathing. See $10\frac{2}{3}$.

$10\frac{2}{3}$ oz. Muntz's metal, or 40 zinc and 60 copper. "Any proportions," says the patentee, "between the extremes 50 zinc and 50 copper, and 37 zinc, 63 copper, will roll and work at the red-heat;" but the first-named proportion, or 40 zinc to 60 copper, is preferred.

The metal is cast into ingots, heated to a red heat, and rolled and worked at that heat into ships' bolts and other fastenings and sheathing.

12 oz. Spelter-solder for copper and iron is sometimes made in this proportion; for brass-work the metals are generally mixed in equal parts. See 16 oz.

12 oz. Pale-yellow metal, fit for dipping in acids, is often made in this proportion.

16 oz. Soft spelter-solder, suitable for ordinary brass-work, is made of equal parts of copper and zinc. About 14 lbs. of each are melted together and poured into an ingot-mould with cross-ribs, which indents it into little squares of about 2 lbs. weight; much of the zinc is lost. These lumps are afterward heated nearly to redness upon a charcoal fire, and are broken up, one at a time, with great rapidity, on an anvil or in an iron pestle and mortar. The heat is a critical point; if too great, the solder is beaten into a cake or coarse lumps, and becomes tarnished; when the heat is proper, it is nicely granulated, and remains of a bright-yellow color; it is afterward passed through a sieve. Of course, the ultimate proportion is less than 16 oz. of zinc.

16 oz. Equal parts is the one extreme of Muntz's patent sheathing. See $10\frac{2}{3}$.

$16\frac{1}{4}$ oz. Hamilton and Parker's patent mosaic gold, which is dark-colored when first cast, but on dipping assumes a beautiful golden tint. "When cooled and broken," say the patentees, "all yellowness must cease, and the tinge vary from reddish-fawn or salmon color to a light purple or lilac, and from that to whiteness." The proportions are stated as from 52 to 58 zinc to 50 of copper, or $16\frac{1}{4}$ to 17 oz. to the pound.

32 oz., or 2 zinc to 1 copper. A bluish-white brittle alloy, very brilliant, and so crystalline that it may be pounded cold in a pestle and mortar.

128 oz., or 2 oz. of copper to every pound of zinc. A hard crystalline metal, differing but little from zinc, but more tenacious; it has been used for laps or polishing-disks.

*Remarks on the Alloys of Copper and Zinc.*—These metals seem to mix in all proportions.

The addition of zinc continually increases the fusibility, but, from the extremely volatile nature of zinc, these alloys cannot be arrived at with very strict regard to proportion.

The red color of copper slides into that of yellow brass at about 4 to 5 oz. to the pound, and remains little altered unto about 8 or 10 oz.; after this it becomes whiter, and when 32 oz. of zinc are added to 16 of copper, the mixture has the brilliant silvery color of speculum metal, but with a bluish tint.

These alloys, from about 8 to 16 oz. to the pound of copper, are extensively used for dipping, as in an enormous variety of furniture-work; in all cases the metal is annealed before the application of the scouring or cleaning processes, and of the acids, bronzes, and lacquers subsequently used.

The alloys with zinc retain their malleability and ductility well, unto about 8 or ten oz. to the pound; after this the crystalline character slowly begins to prevail. The alloy of 2 zinc and 1 copper, before named, may be crumbled in a mortar when cold.

The ordinary range of good yellow brass, that files and turns well, is from about $4\frac{1}{2}$ to 9 oz. to the pound. With additional zinc, it is harder and more crystalline; with less, more tenacious, and it hangs to the file like copper; the range is wide, and small differences are not perceived.

*Alloys of Copper and Tin only.*—The marginal numbers denote the ounces of *tin* added to every pound of copper.

*Ancient Copper and Tin Alloys.*

$\frac{3}{4}$ oz. Ancient bronze nails, flexible, or 20 copper, 1 tin. (*Ure.*)

$1\frac{3}{4}$ oz. Soft bronze, or 9 to 1.
2 oz. Medium bronze, or 8 to 1.
$2\frac{1}{4}$ oz. Hard bronze, or 7 to 1.
{ According to Pliny, as quoted by Wilkinson. Ancient weapons and tools, by various analyses, or 8 to 15 per cent. tin; medals from 8 to 12 per cent. tin, with 2 parts zinc added to each 100, for improving the bronze color. (*Ure.*)

6 to 8 oz. Ancient mirrors.

*Modern Copper and Tin Alloys.*

1 oz. Soft gun-metal, that bears drifting, or stretching from a perforation.

$1\frac{1}{3}$ oz. A little harder alloy, fit for mathematical instruments; or 12 copper and 1 very pure grain tin.

$1\frac{1}{2}$ oz. Still harder, fit for wheels to be cut with teeth.

$1\frac{1}{2}$ to 2 oz. Brass ordnance, or 8 to 12 per cent. tin; but the general proportion is one-ninth part of tin.

2 oz. Hard bearings for machinery.

$2\frac{1}{2}$ oz. Very hard bearings for machinery. By Muschenbroeck's tables it appears that the proportion 1 tin and 6 copper is the most tenacious alloy; it is too brittle for general use, and contains $2\frac{1}{4}$ oz. to the pound of copper.

3 oz. Soft musical bells.

$3\frac{1}{2}$ oz. Chinese gongs and cymbals, or 20 per cent. tin.

4 oz. House-bells.

$4\frac{1}{2}$ oz. Large bells.

5 oz. Largest bells.

$7\frac{1}{4}$ to $8\frac{1}{2}$ oz. Speculum metal. Sometimes 1 oz. of brass is added to every pound, as the means of introducing a trifling quantity of zinc; at other times small proportions of silver are added; the employment of arsenic was strongly advocated by the Rev. John Edwards. Lord Oxmantown, now the Earl of Rosse, says: "Tin and copper, the materials employed by Newton in the first reflecting telescope, are preferable to any other with which I am acquainted; the best proportions being 4 atoms of copper to 1 of tin (Turner's numbers); in fact, 126.4 parts of copper to 58.9 of tin."

32 oz. of tin to 1 lb. of copper make the alloy called by the pewterers "temper," which is added in small quantities to tin for some kinds of pewter, called "tin and temper," in which the copper is frequently much less than 1 per cent.

*Remarks on the Alloys of Copper and Tin only.*—These metals seem to mix in all proportions.

The addition of tin continually increases the fusibility, although, when it is added cold, it is apt to make the copper pasty, or even to set it in a solid lump in the crucible.

The red color of the copper is not greatly impaired in those proportions used by the engineer, namely, up to about 2½ oz. to the pound; it becomes grayish-white at 6, the limit suitable for bells, and quite white at about 8, the speculum metal; after this the alloy becomes of a bluish cast.

The tin alloy is scarcely malleable at 2 oz., and soon becomes very hard, brittle, and sonorous; and when it has ceased to serve for producing sound, it is employed for reflecting light.

The tough, tenacious character of copper under the tools rapidly gives way; alloys of 1½ cut easily, 2½ assume about the maximum hardness without being crystalline; after this they yield to the file by crumbling in fragments rather than by ordinary abrasion in shreds, until the tin very greatly predominates, as in the pewters. When the alloys become the more flexible, soft, malleable, and ductile, the less copper they contain.

*Alloys of Copper and Lead only.*—The marginal numbers denote the ounces of lead added to every pound of copper.

2 oz. A red-colored and ductile alloy.

4 oz. Less red and ductile; neither of these is so much used as the following, as the object is to employ as much lead as possible.

6 oz. Ordinary pot-metal, called dry pot-metal, as this quantity of lead will be taken up without separating on cooling; this is brittle when warmed.

7 oz. This alloy is rather short, or disposed to break.

8 oz. Inferior pot-metal, called wet pot-metal, as the lead partly oozes out in cooling, especially when the new metals are mixed; it is therefore always usual to fill the crucible in part with old metal, and to add new for the remainder. This alloy is very brittle when slightly warmed. More lead can scarcely be used, as it separates on cooling.

*Remarks on the Alloys of Copper and Lead only.*—These metals mix in all proportions until the lead amounts to nearly half; after this they separate in cooling.

The addition of lead greatly increases the fusibility.

The red color of the copper is soon deadened by the lead; at about 4 oz. to the pound the work has a bluish leaden hue when first turned, but changes in an hour or so to that of a dull gun-metal character.

When the lead does not exceed about 4 oz. the mixture is tolerably malleable, but with more lead it soon becomes very brittle and rotten; the alloy is greatly inferior to gun-metal, and is principally used on account of the cheapness of the mixture, and the facility with which it is turned and filed.

*Alloys of Copper, Zinc, Tin, and Lead, etc.*—This group refers principally to gun-metal alloys, to which more or less zinc is added by many engineers; the quantity of tin in every pound of the alloy, which is expressed by the marginal numbers, principally determines the hardness.

Keller's statues at Versailles are found, as the mean of four analyses, to consist of

| | | |
|---|---|---|
| Copper | 91.40, or about | 14⅜ oz. |
| Zinc | 5.53 " | 1 " |
| Tin | 1.70 " | ⅜ " |
| Lead | 1.37 " | ¼ " |
| | In 100 parts or the 16 oz. | |

1½ to 2¼ oz. tin to 1 lb. copper used for bronze medals, or 8 to 15 per cent. tin, with the addition of 2 parts in each 100 of zinc, to improve the color.

The modern so-called bronze medals of our mint are of pure copper, and are afterward bronzed superficially.

| | | | | |
|---|---|---|---|---|
| 1½ oz. tin, | ½ oz. zinc, | to 16 oz. | copper. | Pumps and works requiring great tenacity. |
| 1½ oz. tin, | 2 oz. brass, | 16 | " | For wheels to be cut into teeth. |
| 1¾ " | 2 " | 16 | " | For wheels to be cut into teeth. |
| 2 " | 1½ " | 16 | " | For turning-work. |
| 2¼ " | 1½ " | 16 | " | For nuts of coarse threads, and bearings. |

The engineer who uses these five alloys recommends melting the copper alone; the small quantity of brass is then melted in another crucible, and the tin in a ladle; the two latter are added to the copper when it has been removed from the furnace; the whole are stirred together and poured into the moulds without being run into ingots. The real quantity of tin to every pound of copper is about one-eighth ounce less than the numbers stated, owing to the addition of the brass, which increases the proportion of copper.

1⅞ oz. tin, 1⅞ oz. zinc, to 1 lb. of copper. This alloy, which is a tough, yellow, brassy gun-metal, is used for general purposes by a celebrated engineer; it is made by mixing 1½ lb. tin, 1½ lb. zinc, and 10 lbs. of copper. The alloy is first run into ingots.

2½ oz. tin, ½ oz. zinc, to 1 lb. of copper, used for bearings to sustain great weights.

2½ oz. tin, 2½ oz. zinc, to 1 lb. of copper, were mixed by the late Sir F. Chantry, and a razor was made from the alloy; it proved nearly as hard as tempered steel, and exceedingly destructive to new files, and none others would touch it.

1 oz. tin, 2 oz. zinc, 16 oz. brass. Best hard white metal for buttons.

½ oz. tin, 1½ oz. zinc, 16 oz. brass. Common ditto. (*Phillips's Dictionary.*)

10 lbs. tin, 6 lbs. copper, 4 lbs. brass, constitute white solder. The copper and brass are first melted together, the tin is added, and the whole stirred and poured through birch twigs into water to granulate it; it is afterward dried and pulverized cold in an iron pestle and mortar. This white solder was introduced as a substitute for silver solder in making gilt buttons. Another button-solder consists of 10 parts copper, 8 of brass, and 12 of spelter or zinc.

*Remarks on Alloys of Copper, Zinc, Tin, Lead, etc.*—*Ordinary Yellow Brass* (copper and zinc) is rendered very sensibly harder, so as not to require to be hammered, by a small addition of tin, say one-quarter or one-half oz. to the pound. On the other hand, by the addition of one-quarter to one-half oz. of lead, it becomes more malleable and casts more sharply. Brass becomes a little whiter for the tin, and redder for the lead. The addition of nickel to copper and zinc constitutes the so-called German silver.

*Gun-Metal* (copper and tin) very commonly receives a small addition of zinc; this makes the alloy mix better, and to lean to the character of brass by increasing the malleability without materially reducing the hardness. The standard measures for the Exchequer were made of a tough alloy of this kind. The zinc, which is sometimes added in the form of brass, also improves the color of the alloy, both in the recent and bronzed states. Lead, in small quantity, improves the ductility of gun-metal, but at the expense of its hardness and color; it is seldom added. Nickel has been proposed as an addition to gun-metal by Mr. Donkin, and antimony by Dr. Ure.

Some important experiments in regard to the strength of gun-metal, as affected by heat and as compared with the strength of some other metals under like conditions, have been made by the British Admiralty (see "Engineering," vol. xxiv., No. 614). Five rods 1 inch in diameter were made respectively of the following compositions: No. 1—copper, 87.75; tin, 9.75; zinc, 2.5. No. 2—copper, 91; tin, 7; zinc, 2. No. 3—copper, 85; tin, 5; zinc, 10. No. 4—copper, 83; tin, 2; zinc, 15. No. 5—copper, 92.5; tin, 5; zinc, 2.5. These were gradually heated in an oil-bath up to 500° Fahr. It appears that all the varieties of gun-metal suffer a gradual but not serious loss of strength and ductility up to a certain temperature, at which, within a few degrees, a great change takes place; the strength falls to about one-half the original, and the ductility is wholly gone. At temperatures above this point, up to 500°, there is little, if any, further loss of strength. The precise temperature at which this great change and loss of strength takes place, although uniform in the specimens cast from the same pot, varies about 100° in the same composition cast at different temperatures, or with some varying conditions in the foundery process. The precise temperature at which the change took place in No. 1 series was ascertained to be about 370°, while in another bar of similar composition the change occurred at a little over 250°. The possibility of such a change taking place at a temperature so low in the best gun-metal, used for the more important parts of machinery and boiler-mountings, is serious.

Phosphor-bronze, the only metal in the series which, from its strength and hardness, could be used as a substitute, was less affected by temperature, and at 500° retains more than two-thirds of its strength and one-third its ductility.

Rolled Muntz metal and copper are satisfactory up to 500°, and may be used as securing bolts with safety.

*Pot-Metal* (copper and lead) is improved by the addition of tin, and the three metals will mix in almost any proportions. When the tin predominates, the alloy so much the more nearly approaches the condition of gun-metal. Zinc may be added to pot-metal in very small quantity, but when the zinc becomes a considerable amount, the copper takes up the zinc, forming a kind of brass, and leaves the lead at liberty, and which, in great measure, separates in cooling. Zinc and lead are also very indisposed to mix alone, although a little arsenic assists their union by "killing" the lead, as in shot-metal. Antimony also facilitates the combination of pot-metal; 7 lead, 1 antimony, and 16 copper, mixed perfectly well the first fusion, and the alloy was decidedly harder than 4 lead and 16 copper, and apparently a better metal. "Lead and antimony, though in small quantity, have a remarkable effect in diminishing the elasticity and sonorousness of the copper alloys."

Prof. R. H. Thurston has conducted a very extended series of investigations into the properties of certain copper alloys, and has deduced the following principal results:

*Copper-Zinc Alloys.*—The experiments upon copper-zinc were begun by casting one series of 21 bars, each 28 inches in length and 1 inch square in section, and then a second series of 20 bars of similar size. In the first series the proportions of zinc and copper differed regularly for each bar, to the extent of 5 per cent., bar 1 containing 5 per cent. of zinc, bar 2, 10 per cent., and so on up to 100 per cent. of pure zinc. In the second series the first bar contained 2½ per cent. and the last 97½ per cent. of zinc, the relative differences being the same.

By examination of the color of these various alloys it appears that they may be divided into three clearly-marked classes, viz.: the yellow alloys, which excludes all those containing less than 55 per cent. of zinc; the silver-white and brilliant alloys, containing between 60 and 70 per cent. of zinc; and the bluish-gray alloys, containing more than 75 per cent. of zinc. On applying tests for transverse strength, it appears that the first class above noted may be separated into two divisions, one showing considerably more strength than the other; in the first are included the bars containing from 17.99 to 33.50 zinc (and probably all the alloys from pure copper to the latter limit). These show a modulus of rupture (by which is meant a value proportional to the transverse strength of a bar, and which is theoretically equivalent to 1½ times the load which would break a bar of 1 unit in length, breadth, and depth, supported at both ends, and loaded in the middle) from 21,000 to 28,000, and are characterized by great ductility and an earthy fracture. The second division includes alloys from 38.65 zinc to 52.28 zinc inclusive, which show greater strength than the preceding. The point of maximum strength is determined to be between 38.65 zinc and 44.94 zinc. The second class of alloys show great weakness and lack of ductility. The minimum strength was found in alloy of 65 per cent. zinc, the modulus of rupture being but one-tenth of the maximum. Alloys of the third class showed much greater strength than those of the second, but not equal to that of those of the first.

In tensile strength, alloys containing up to 50 per cent. zinc average 30,000 lbs. to the square inch, and are classed as useful metals. 60, 65, and 70 per cent. zinc alloys are very weak, the highest average being that of the 60 per cent. alloy, which is 3,727 lbs. to the square inch. The remainder of the 21, or third class, average from 18,065 to 5,400 lbs. per square inch, pure zinc being the weakest. The maximum strength is possessed by an alloy containing somewhat less than 44 per

cent. of zinc, and the minimum tenacity is 1,774 lbs. per square inch in an alloy of 70 per cent. zinc. In torsional tests the average results agreed with the foregoing. In compression the 55 per cent. alloy showed a maximum of 121,000 lbs. to the square inch, pure zinc yielding at 22,000 lbs. Tests conducted on the second series of alloys closely confirm the results already stated, and need not be detailed.

It is well known that, no matter how accurately alloys may be compounded, chemical analysis of the metal after casting often reveals a notably different composition. In analyzing the copper-zinc alloys above noted, it was found that the only general difference between the components of the original mixtures and those determined by analysis was that in almost every case a smaller percentage of zinc appeared, and a larger percentage of copper. The real decrease of zinc is believed to be due to volatilization of the metal in melting and casting. The average loss was from 1 to 2 per cent. in a bar. In several bars a considerable amount of liquation took place, and in general the upper end of the bar contained the highest percentage of copper.

The variation of specific gravity with change of composition follows a very definite law, decreasing very regularly with the increase in percentage of zinc. None of the zinc-copper alloys have a greater density than that of pure zinc, the only apparent exceptions being caused by the presence of pores and other flaws.

*Copper-Tin Alloys.*—In the experiments on the copper-tin alloys, bars of the same size as already noted were first cast. Two series of alloys were prepared, the first numbering 30 compositions, beginning with pure copper, and then varying in percentages of tin from 1.9 up to 99.44, and ending in pure tin. The second series consisted of 20 bars ranging from 97½ per cent. copper and 2½ per cent. tin to 97½ per cent. tin and 2½ per cent. copper, with a regular difference of 5 per cent.

Alloys containing respectively 1.9, 3.73, 7.20, 10, 13.43, 20, and 23.68 per cent. tin were found to have considerable strength; and all the rest of series 1 are stated to be practically useless where strength is a requirement. The dividing-line between the strong and brittle alloys is precisely that at which the color changes from golden-yellow to silver-white, viz., at a composition containing between 24 and 30 per cent. of tin. Alloys containing more than 24 per cent. of tin are comparatively valueless. Tests by tension give results according with the foregoing. Generally it appears that the tensile and compressive strengths of the alloys are in no way related to each other; that the torsional strength is closely proportional to the tensile strength, and that the transverse strength may depend in some degree upon the compressive strength; but it is much more nearly related to the tensile strength, as is shown by the general correspondence of the curve of the transverse with that of the tensile strength. The maximum crushing strength was given by the 30 per cent. tin alloy, and the minimum by pure tin.

The results of the tests for transverse strength on the second series do not seem to corroborate the theory given by some writers, that peculiar properties are possessed by the alloys which are compounded of simple multiples of their atomic weights or chemical equivalents, and that these properties are lost as the composition varies more or less from this definite constitution. It does appear that a certain percentage composition gives a maximum strength, and another certain percentage a minimum; but neither of these compositions is represented by simple multiples of the atomic weights. Besides, there appears to be a perfectly regular law of decrease from the maximum to the minimum strength, which does not seem to have any relation to the atomic proportions, but only to the percentage composition. On analyzing the copper-tin alloys, there appears to be a greater loss of tin than of copper in the bars which contain the greater percentage of copper, and a greater loss of copper than of tin in the bars which contain the largest percentage of tin; and that the bars which contain about equal amounts of the two metals show a great tendency to liquation. In the alloys containing less than 35 per cent. of tin by original mixture there is a greater loss of tin than of copper, with but three exceptions. In the alloys containing more than 70 per cent. of tin there is a greater loss of copper than of tin, with only one exception. In all of the alloys of these two classes the extreme variation of a single mixture is 3.6 per cent., and generally it is less than 1 per cent. It further appears that the actual specific gravities of all the alloys containing less than 25 per cent. of tin does not greatly vary from 8.95.

*Japanese and Chinese Bronzes.*—Magnificent objects of art produced from these alloys attracted great attention at the Centennial Exposition of 1876.

The Japanese alloys are mostly used for ornamental castings, statues, musical instruments, and bells. The name given to an alloy generally corresponds to the color produced by the treatment which the objects have to undergo before they are finished; thus some of the alloys are named green copper, violet copper, black copper, etc. This color depends both upon the composition of the alloy and the chemicals used in coloring the metal. There are many different means used to produce one and the same color, and it so happens that almost every manufacturer uses particular compositions of his own; generally it is only the proportions that differ, but sometimes even the constituent elements are different, although the alloy is called by the same name.

The "green copper" (Sei-Do) is composed of copper and lead, or copper, lead, and tin; the Sentoku-do, of copper, lead, and spelter, and similar to the old Corinthian alloy, is said to have been first produced by a large conflagration which took place in China during the earlier part of the fifteenth century. The black alloy called U-do, of copper, lead, and tin; the brass, of copper and spelter, sometimes with a slight addition of lead, as, for instance, in Yechiu, one of the chief places of production of ornamental castings, inlaid with gold and silver; the purple alloy is composed of copper and lead; the so-called Gin-shibu-ichi is generally composed of 4 parts of copper or alloy and 6 parts of silver. Another peculiar composition is the Shakudo, copper with a small percentage (2 to 5 per cent.) of gold, which produces a beautiful dark-blue color, and is mostly used for articles formed by hammering, or for *repoussé* work, generally inlaid with gold and silver, and producing designs somewhat similar to the so-called "Niello" work.

A very beautiful production is Mokume, a word meaning "veins of the wood." Pieces of this metal are produced by overlaying and soldering together a certain number of plates of alloys of silver, red copper, and a blue alloy. These are hammered, kneaded, resoldered, and the hollow spaces filled up with new metal. Finally, when stretched out in a thin sheet, an exquisite marbled pattern is produced. Messrs. Tiffany & Co., of New York City, have succeeded also in making this curious combination in great beauty. M. Morin has analyzed various Japanese bronzes, and considers that the *patina* of black bronzes forms part of the metal, and is not due to a varnish or a superficial sulphurization, but results from the use of a bronze of rather complex nature, in which are 80 per cent. of copper, 4 of tin, 10 of lead, 2 of zinc, and 4 of iron, gold, nickel, arsenic, and sulphur. Some of the bronzes analyzed show a proportion of lead varying from 10 to 20 per cent. added at the expense of the copper, and a quantity of 7 per cent. of tin. Moulded in very thin plates, this bronze readily takes any form given to it, and is easily worked, the *patina* appearing of itself when the finished work of art is subjected, in a muffle-furnace, to the action of a very high temperature. Unfortunately, these bronzes are very brittle. Fine imitations of Japanese bronzes are made in France by peculiar chemical treatment of metallic surfaces.

*Phosphor-Bronze.*—By the addition of a small percentage of phosphorus to bronze alloy, the qualities of the latter become more and more changed, the grain or fracture becomes finer, the color brighter, the elasticity and resistance to strain and compression increase considerably, and when melted it attains great fluidity. Messrs. Montefiore and Künzel have experimented with alloys of copper and nickel, and with manganese—binary alloys; also with ternary—bronzes of copper, tin, and manganese, with copper, tin, and nickel, as well as with iron alloyed with copper and tin. The manganese alloys they concluded to be entirely useless, as also those of nickel and of iron. They obtained great tensile strength and hardness with some of these compositions, but their ready oxidability at high temperatures made the qualities of the castings uncertain and impracticable.

The action of phosphorus is twofold: 1. It eliminates the oxides, as stated above; and, 2. It makes the tin capable of adopting a crystalline structure; and as two crystalline metals form a much more homogeneous alloy than two metals of which one is not crystalline, phosphor-bronze must necessarily be more homogeneous than ordinary bronze. Homogeneity and absence of oxygen increase the elasticity and absolute resistance of the alloy. Another great advantage of phosphor-bronze is that its hardness can be regulated by varying the proportion of phosphorus, which, in ordinary bronze, is done by increasing the proportion of tin, whereby the danger of segregation in the casting is greatly augmented. Ordinary bronze, after one or two smeltings, becomes thick-flowing and putty-like, while phosphor-bronze remains perfectly liquid until the moment it sets—solidifies; if, therefore, it is cast just before the "setting" takes place, no segregation is possible. Combinations of phosphorus with copper, with tin, or with other metals, have long been known by chemists, but Dr. Künzel was the first to employ the same for the purposes above stated. A number of phosphor-bronze alloys are now manufactured, varying in composition to suit the objects for which they are intended. The scope of their applications is of course very great. The harder alloys are used for casting bells, tools for gunpowder mills, etc.; other somewhat softer alloys are used for engineering purposes, and the still softer for rolling, drawing, and embossing, etc.

The following tables will show the results of tests made by Mr. Kirkaldy with various phosphor-bronze alloys:

| CAST METAL. | Diminution of Section before Rupture. | Resistance in Pounds per Square Inch. | |
|---|---|---|---|
| | | Elastic. | Absolute. |
| | Per cent. | lb. | lb. |
| Pure copper | 3.30 | 4.4000 | 6.975 |
| Ordinary gun-metal, containing 9 parts copper and 1 part tin | 3.60 | 12.800 | 16.650 |
| Phosphor-bronze | 8.40 | 23.800 | 52.625 |
| " " | 1.50 | 24.700 | 46.100 |
| " " | 33.40 | 16.100 | 41.448 |

| DRAWN METAL. | Pulling Stress per Square Inch. | | Twists in 5 Inches. | | Ultimate Extension. |
|---|---|---|---|---|---|
| | Wire as drawn. | Annealed. | Wire as drawn. | Annealed. | |
| Various alloys: | lb. | lb. | lb. | lb. | Per ct. |
| Phosphor-bronze | 102.759 | 49.351 | 6.7 | 89 | 37.5 |
| " " | 120.957 | 47.787 | 22.3 | 52 | 34.1 |
| " " | 120.950 | 53.381 | 13.0 | 124 | 42.4 |
| " " | 139.141 | 54.111 | 17.3 | 53 | 44.9 |
| " " | 159.515 | 58.853 | 13.3 | 66 | 46.6 |
| " " | 151.119 | 64.569 | 15.8 | 60 | 42.8 |
| Copper | 63.122 | 37.002 | 86.7 | 96 | 34.1 |
| Steel | 120.976 | 74.637 | 22.4 | 79 | 10.9 |
| Iron, galvanized, best charcoal E | 65.834 | 46.160 | 48.0 | 87 | 28.0 |

A series of interesting experiments with phosphor-bronze were made in Berlin by the Royal Academy of Industry, in order to ascertain the qualities and capacities of the metal while under heavy strain, and its resistance to often repeated strains. The first bar of phosphor-bronze was tried under a constant strain of 10 tons per square inch, and resisted 408,230 pulls; a bar of ordinary bronze broke even before the strain of 10 tons per square inch had been attained. A second bar of phosphor-bronze was tried under a strain of 12½ tons per square inch, and withstood 147,850 pulls; and a third bar, under 7½ tons strain, broke only after 3,100,000 pulls. On the bending-machine, phosphor-bronze, while under 9 tons strain per square inch, remained unbroken after 4,000,000 bends, while ordinary bronze broke after 150,000 bends. Major Majendie tested phosphor-bronze as to its liability to emit sparks when subject to friction, and attained very satisfactory results. A grindstone of 9 inches diameter was made to revolve very rapidly, so that any point on the grinding-face would describe a distance of 2,000 feet per minute; the metal was then pressed against the revolving stone, and the results proved that the harder descriptions of phosphor-bronze emit sparks less readily than the softer samples, and much less readily than ordinary gun-metal or copper.

For frictional purposes a special alloy is made by fusing phosphor-bronze in certain proportions, together with another soft alloy of different degree of fusibility, so as to produce by cooling the given alloys. The shell is then formed of a very tough and hard phosphor-bronze, and the interior of aforesaid soft alloy. The bearing-surface may then be considered to consist of a large number of small bearings of soft metal, inclosed in castings of metal almost as hard as the arbor itself. The microscope reveals this disposition very plainly; and if one of these bearings be carefully submitted to heat, so as to cause the soft fusible metal to run off, the rest will remain in the form of a spongy mass. Bearings, slides, eccentrics, etc., of this peculiar alloy are now very largely in use, and the practical results show that it wears more than five times as long as gun-metal.

Phosphor-bronze is readily rolled or beaten out into sheets. In Russia it has been used as a material for cartridge sheathing, and specimens have stood 120 trials without tearing. Sheets of the alloy stand the action of sea-water much better than copper. In a comparative experiment made at Blankenberg, lasting over a period of six months, between the best English copper and phosphor-bronze, the following results were arrived at:

| THICKNESS OF THE SHEETS = 0.236 Inches. | Weight before Immersion. | Weight after Immersion. | Loss of Weight. | |
|---|---|---|---|---|
| | lb. | lb. | lb. | Per cent. |
| Sheet of copper | 74.4 | 72.2 | 2.2 | 3.015 |
| " " | 88.9 | 86.2 | 2.7 | 3.100 |
| Sheet of phosphor-bronze | 69.5 | 68.75 | 0.75 | 1.123 |
| " " " | 114.3 | 112.97 | 1.33 | 1.195 |

The loss in weight, therefore, due to the oxidizing action of sea-water during the six months' trial, averaged for the English copper 3.058 per cent., while that of the phosphor-bronze was but 1.158 per cent., or about one-third. Several Governments have experimented on the use of the alloy for making cannons. Without any exception, the results showed a much greater resisting power than that possessed by ordinary bronze.*

*Gold Alloys.*—Gold in the pure or fine state is not employed in bulk for many purposes in the arts, as it is then too soft to be durable. The gold foil used by dentists for stopping decayed teeth is perhaps as nearly pure as the metal can be obtained: it contains about 6 grains of alloy in the pound troy, or the one-thousandth part. Every superficial inch of this gold foil or leaf weighs three-fourths of a grain, and is 42 times as thick as the leaf used for gilding.

The wire for gold lace, prepared by the refiners for gold-lace manufacturers, requires equally fine gold, as, when alloyed, it does not so well retain its brilliancy. The gold, in the proportion of about 100 grains to the pound troy of silver, or of 140 grains for double-gilt wire, is beaten into sheets as thin as paper; it is then burnished upon a stout red-hot silver bar, the surface of which has been scraped perfectly clean. When extended by drawing, the gold still bearing the same relation as to quantity, namely, the 57th part of the weight, becomes of only one-third the thickness of ordinary gold-leaf used for gilding. In water-gilding, fine gold is amalgamated with mercury and washed over the gilding metal (copper and tin); the mercury attaches itself to the metal, and, when evaporated by heat, it leaves the gold behind in the dead or frosted state: it is brightened with the burnisher. By the electrotype process, a still thinner covering of pure gold may be deposited on silver, steel, and other metals. Mr. Dent has introduced this method of protecting the steel pendulum-springs of marine chronometers and other time-pieces from rust.

Fine gold is also used for soldering chemical vessels made of platinum.

Gold leaf, for gilding, contains from 3 to 12 grains of alloy to the ounce, but generally 6 grains. The gold used by respectable dentists for plates is nearly pure, but necessarily contains about 6 grains of copper in the ounce troy, or one-eightieth part. Others use gold containing upward of one-third of alloy: the copper is then very injurious.

With *Copper*, gold forms a ductile alloy of a deeper color, harder and more fusible than pure gold. This alloy, in the proportion of 11 of gold to 1 of copper, constitutes *standard gold;* its density is 17.157, being a little below the mean, so that the metals slightly expand on combining. One troy pound of this alloy is coined into $46\frac{29}{40}$ sovereigns, or 20 troy pounds into $934\frac{1}{2}$ sovereigns. The pound was formerly coined into $44\frac{1}{2}$ guineas. The standard gold of France consists of 9 parts of gold and 1 of copper. (*Brande*, 979.)

For *Gold Plate* the French have three different standards: 92 parts gold, 8 copper; also 84 gold, 16 copper; and 75 gold, 25 copper.

In England, the purity of gold is expressed by the terms 22, 18, 16 carats, etc. The pound troy is supposed to be divided into 24 parts, and the gold, if it could be obtained perfectly pure, might be called 24 carats fine.

The "Old Standard Gold," or that of the present currency, is called fine, there being 22 parts of pure gold to 2 of copper.

The "New Standard," for watch-cases, etc., is 18 carats of fine gold and 6 of alloy. No gold of inferior quality to 18 carats, or the "New Standard," can receive the Hall mark; and gold of lower quality is generally described by its commercial value, as 60 or 40 shilling gold, etc.

The alloy may be entirely silver, which will give a green color, or entirely copper for a red color; but the copper and silver are more usually mixed in the one alloy, according to the taste and judgment of the jeweler.

* Abridged from a lecture delivered by Mr. A. Dick before the Society of Arts, 1877.

The following alloys of gold are transcribed from the memoranda of the proportions employed by a practical jeweler of considerable experience: *

*First Group.*—Different kinds of gold that are finished by polishing, burnishing, etc., without necessarily requiring to be colored.

The gold of 22 carats fine, or the "Old Standard," is so little used, on account of its expense and greater softness, that it has been purposely omitted.

18 carats, or New Standard gold, of yellow tint: *

15 dwt. 0 grs. gold.
2 dwt. 18 grs. silver.
2 dwt. 6 grs. copper.

20 dwt. 0 grs.

18 carats, or New Standard gold, of red tint: *

15 dwt. 0 grs. gold.
1 dwt. 18 grs. silver.
3 dwt. 6 grs. copper.

20 dwt. 0 grs.

16 carats, or spring-gold. This, when drawn or rolled very hard, makes springs little inferior to those of steel:

1 oz. 16 dwt. gold, or 1.12
6 dwt. silver, — .4
12 dwt. copper, — .12

2 oz. 14 dwt. 2.8

60*s.* gold of yellow tint, or the fine gold of the jewelers—16 carats nearly:

1 oz. 0 dwt. gold.
7 dwt. silver.
5 dwt. copper.

1 oz. 12 dwt.

60*s.* gold of red tint, or 16 carats:

1 oz. 0 dwt. gold.
2 dwt. silver.
8 dwt. copper.

1 oz. 10 dwt.

40*s.* gold, or the old-fashioned jewelers' gold, about 11 carats fine; no longer used:

1 oz. 0 dwt. gold.
12 dwt. silver.
12 dwt. copper.

2 oz. 4 dwt.

*Second Group.*—Colored golds: these all require to be submitted to the process of wet-coloring, which will be explained. They are used in much smaller quantities, and require to be very exactly proportioned.

Full red gold:

5 dwt. gold.
5 dwt. copper.

10 dwt.

Red gold:

10 dwt. gold.
1 dwt. silver.
4 dwt. copper.

15 dwt.

Blue gold, scarcely used:

5 dwt. gold.
5 dwt. steel filings.

10 dwt.

Green gold:

5 dwt. 0 grs. gold.
21 grs. silver.

5 dwt. 21 grs.

Gray gold (platinum is also called gray gold by jewelers):

3 dwt. 15 grs. gold.
1 dwt. 9 grs. silver.

5 dwt. 0 grs.

Antique gold, of a fine greenish-yellow color:

18 dwt. 9 grs. gold, or 18. 9
21 grs. silver, — 1. 3
18 grs. copper, — .12

20 dwt. 0 grs. 20. 0

*Third Group.*—Gold solders: these are generally made from gold of the same quality and value as they are intended for, with a small addition of silver and copper, thus:

Solder for 22-carat gold:

1 dwt. 0 grs. of 22-carat gold.
2 grs. silver
1 gr. copper.

1 dwt. 3 grs.

Solder for 18-carat gold:

1 dwt. 0 grs. of 18-carat gold.
2 grs. silver.
1 gr. copper.

1 dwt. 3 grs.

Solder for 60*s.* gold: *

1 dwt. 0 grs. of 60*s.* gold.
10 grs. silver.
8 grs. copper.

1 dwt. 18 grs.

Solder for 40*s.* gold; but middling silver solder is more generally used:

1 dwt. fine gold.
1 dwt. silver.
2 dwt. copper.

4 dwt.

* When it is not otherwise expressed, it will be understood all these alloys are made with fine gold, fine silver, and fine copper, obtained direct from the refiners. And to insure the standard gold passing the test of the Hall, 3 or 4 grains additional of gold are usually added to every ounce.

Dr. Hermstadt's imitation of gold, which is stated not only to resemble gold in color, but also in specific gravity and ductility, consists of 16 parts of platinum, 7 parts of copper, and 1 of zinc, put in a crucible, covered with charcoal powder, and melted into a mass.

Gold alloyed with platinum is also rather elastic, but the platinum whitens the alloy more rapidly than silver.

When 12 parts *manganese* and 88 parts gold are melted together, an alloy is produced having a pale yellowish-gray color, with considerable lustre and hardness, and little ductility. Its fracture is granular and spongy. It is less easily fusible than gold, and the manganese may be completely separated by roasting.

*Iron* and gold have a strong affinity for each other, and the latter may be united in all proportions with steel or cast-iron. Gold may be used for soldering iron. An alloy with 8 per cent. of iron is of a pale yellowish-gray color, very ductile and tenacious, and harder than gold. With from 15 to 20 per cent. of iron, the alloy is gray, and will take a very beautiful polish. It is used in jewelry under the name of gray gold. When 75 to 80 per cent. of iron is alloyed with gold, it has the color of silver, and is so hard as to be applicable to the purposes of cutting-instruments.

*Cobalt* readily unites with gold, and forms alloys of a dull yellow color, which are brittle when the proportion of cobalt is one-sixtieth.

*Nickel* and gold have a brass-yellow color, and are also brittle.

*Copper* has a great affinity for gold, and combines in all proportions. It heightens the color of gold and increases its hardness, while its ductility is somewhat impaired. The maximum hardness is attained with one-eighteenth copper. These alloys, being more fusible than gold, are used for soldering this metal.

The alloy called *jewelers' gold* should contain at least 74.6 of gold. In France, according to Berthier, it varies from 92 to 25 per cent. In Great Britain, 18 carats, or 75 per cent., is the standard for jewelers' gold, although the proportion of this metal is rarely so much. In Sweden it is 76.6 per cent., it being there, as in most parts of Europe, regulated by law. In the United States the standard of gold is not subjected to any legal provision, except in regard to coin, which must contain 9 parts gold to 1 alloy, of which alloy at least one-half must be silver. In Great Britain the coin consists of 11 parts gold and 1 copper; and in France, 10 parts of gold and 1 part of copper.

In order to deepen the color of gold alloyed with silver, artists have a mode of alloying a small portion of copper with the surface only, which is done in the following manner: 1 oz. of yellow wax is melted, and there is added to it a mixture of 2 oz. calcined alum, 12 oz. red chalk, 2 oz. verdigris, and 2 oz. peroxide of copper (copper scales). The four last named must be ground to an impalpable powder, completely mixed with the melted wax, and moulded into sticks for use. After the surface of the gold is well rubbed over with these sticks, the article must be exposed to heat sufficient to burn off the wax entirely. It is then burnished, and washed with a liquor composed of one pint of water to 2 oz. ashes produced by calcining argal or crude tartar, 2 oz. common salt, and 4 oz. sulphur.

*Antimony* unites easily with gold, and produces alloys of a color more or less pale, according to the proportions used. They are brittle, and have a dull, granular fracture. The presence of a very minute proportion of antimony destroys the ductility of gold. It was from this faculty to render brittle, which antimony exerts over all the other metals, that the earlier chemists gave it the title of *regulus*, or *little king*. To its sulphuret was given the name of *lupus metallorum*, because, in the purification of gold, its feeble affinity allowed it to yield the sulphur to the inferior metals, while itself combined with the gold. The sulphuret is still used for the same purpose.

*Tin* forms, with gold, compounds more fusible than the latter; they are ductile when cold, but crumble at a red heat, if the proportion of tin be as much as one-thirty-seventh. With one-twelfth tin the alloy is of a pale-yellow color, but slightly ductile, and has an earthy fracture.

*Zinc*, in small proportion, renders gold brittle; even its vapors sensibly produce this effect on gold in fusion. With one-tenth zinc the alloy is very brittle, and has the color of brass. With one-half zinc it is white, very hard, and takes a high polish. Hellat asserts that an alloy of 7 parts zinc and 1 part of gold is entirely volatilized in a furnace.

*Bismuth* forms, with gold, brittle alloys of a brassy color. The vapor of bismuth is also sufficient to diminish the ductility of gold.

*Lead* forms alloys with gold which are brittle in every proportion. It requires but 1 part of lead in 500,000 of gold to alter sensibly its ductility. An alloy consisting of 1 part lead and 12 parts gold is extremely brittle, and has a dull granular fracture similar to that of porcelain.

*Silver* and gold may be united by rapid fusion in all proportions; but if the fused mass be very slowly cooled, part of the silver, in combination with a small proportion of gold, separates and floats upon the surface, leaving beneath an alloy of 5 parts gold and 1 part silver. The alloys of these metals are more fusible than gold, and have a greenish tinge; even 5 per cent. of silver produces a decided change of color. The proportions used for the *green gold* of the jewelers are 70.8 of gold and 29.2 of silver. These alloys are very ductile, and are harder, more elastic, and more sonorous than either of the metals themselves. The maximum hardness is attained when the proportion of silver is one-third.

*Platinum* may be united with gold in all proportions; but, to produce an alloy completely homogeneous, it should be exposed to a very high temperature, so as to effect a perfect fusion. These alloys are ductile and elastic. When they contain from 7 to 10 per cent. of platinum the color is dull yellow, like tarnished silver. With one-fifth it exactly resembles platinum; with one-seventeenth platinum it is in appearance not distinguishable from gold.

Platinum and silver together combine with gold in all proportions, forming double alloys which are ductile, and possess more stiffness and elasticity than alloys of gold and silver only. Platinum is sometimes introduced into an alloy of silver, gold, and copper, called *doré*, and it is not easy to detect the fraud.

*Palladium* and gold form alloys with less ductility than that of the pure metals. They have a granular structure, and vary in color from white to gray. With equal parts it is nearly white, and a very small proportion lessens the color of gold.

*Rhodium* and gold form alloys, according to Del Rio, which are brittle, unless the proportion of the former be very small, when it hardens the gold without impairing its ductility. With one-seventh rhodium the color is unaltered—a striking difference between its effects and those of platinum and palladium upon gold.

*Iridium*, in being alloyed with gold, but slightly affects it color, and produces ductile alloys.

*Osmium* also forms ductile alloys with gold.

*Arseniurets* of gold (as alloys of arsenic with gold are termed) may be formed by exposing heated gold to the vapor of arsenic. The gold absorbs a very small proportion, but retains it with so strong an affinity that it cannot be entirely separated even at a very high temperature. This alloy is brittle.

*Tellurium* may be combined with gold artificially, by treating the latter in solution with tellureted hydrogen gas. The native combinations of these metals found in Transylvania will be noticed among the ores of gold.

*Mercury* and gold form alloys called *amalgams*. They may be formed by immersing or agitating gold in mercury, which dissolves it even at common temperatures; but the combination is hastened by heat. An alloy saturated with gold, and compressed in chamois skin, is white, and at first soft, but soon becomes solid. It crystallizes in four-sided prisms, and contains 2 parts of gold and 1 of mercury. When sufficiently soft to be kneaded between the fingers, it contains 6 or 7 parts mercury and 1 of gold. Amalgams are used in *gilding*.

*Iridium Alloys.*—Iridium is usually mingled with platinum, the alloys of which see.

*Iron Alloys.—Iron and Copper.*—Direct union difficult, but an apparently homogeneous alloy can be obtained by the simultaneous reduction of the oxides of iron and copper. 0.0286 per cent. of copper diminishes the tenacity of malleable iron; 0.5 per cent. of copper in wrought-iron or steel renders it red-short; 2 per cent. makes steel brittle.

*Iron and Zinc* yield, when heated together, a crystalline friable alloy of no value. So-called galvanized iron is iron covered with a thin alloy of iron and zinc. The iron is immersed in dilute sulphuric acid to clear off rust, and is passed through a bath of molten zinc covered with sal ammoniæ.

*Aich Metal* is copper 60 per cent., zinc 38 to 44, and iron 5 to 3 per cent. It is very ductile.

*Sterro Metal* is a similar alloy, containing copper 60, zinc 34 to 44, malleable iron 2 to 4, and tin 1 to 2.

*Iron and Tin*, when heated together, combine in various proportions, producing alloys varying from gray to white in color, with a granular crystalline fracture, somewhat brittle, and harder than tin. When a clean surface of sheet-iron is immersed in a bath of molten tin, a firm adherent coating of a highly stanniferous alloy is deposited on the surface, the plate so prepared constituting the ordinary tin-plate.

*Iron and Titanium.*—By the treatment of titaniferous iron ores in the blast-furnace, pig-iron has been obtained containing upward of 1 per cent. of titanium, either alloyed or disseminated through the iron; but the malleable iron or steel produced therefrom affords no evidence of its presence.

*Iron and Manganese.*—The necessity of an alloy rich in manganese for the success of the Bessemer steel process has given rise to ferro-manganese, which is obtained by reducing peroxide of manganese, charcoal, and granulated scrap or cast iron in graphite crucibles. Carbonate of manganese and oxide of iron, with excess of charcoal in the specially-prepared bed of the Siemens furnace, result in a fusible alloy of carbon, iron, and manganese. See *Manganese Alloys.*

*Iron and Tungsten.*—Tungsten may be mixed with iron by fusion in all proportions, and the larger the quantity of tungsten, the harder and more difficult to melt is the compound. Like carbon, it appears to diminish the ductility of iron both when hot and cold, but especially when cold. It is then possible, by melting together tungsten and iron, to obtain a steel much harder than one with carbon alone, without the danger of incurring at the same time an excessive fragility when cold, or difficulties of working when hot. For uses which require a special degree of hardness, a steel rich in tungsten, called "special steel," is frequently employed. Thus a fine Sheffield steel for lathe tools, according to an analysis made by Baron Barnekow in the laboratory of the Stockholm School of Mines, contained 9.3 per cent. of tungsten and 0.7 per cent. of silicium, with only 0.6 per cent. of carbon. This steel, which is used, without being tempered, for turning cylinders cast of hard iron, is of sufficient hardness to scratch glass, and yet it is not fragile, for great difficulty is experienced in breaking a ¾-inch square bar. Prof. Heeren has also found, in a special steel of Mushet's, 8.3 per cent. of tungsten and 1.73 per cent. of manganese; this steel seems by its properties to be analogous to that mentioned above. In another special steel from Howell, Sheffield, 2.863 per cent. of tungsten and 1.15 per cent. of carbon were found.

Tungsten is added for obtaining not only a steel of great hardness, but one of moderate hardness combined with a great softness and high ductile capacity. Thus, a steel which would seem to be suitable for the tubes of cast-iron cannons gave, on analysis by Tamm: Carbon, 0.52 per cent.; silicium, 0.04 per cent.; tungsten, 0.3 per cent.; phosphorus, 0.04 per cent.; sulphur, 0.005 per cent. Tested by Styffe, it showed a strength of 77½ tons per square inch, with a ratio of the section of rupture to the original section represented by 0.54. The mean lengthening after rupture was 13 per cent., without taking into account the striction, or reduction of area due to tension, produced by the rupture, and which extended itself over about three-fourths of an inch.

*Iron and Lead.*—No good alloy known.

*Iron and Nickel.*—The alloys of iron and nickel are whiter than iron, are magnetic, capable of receiving a high polish, and are not so easily affected by air or moisture as iron alone. A natural alloy of iron and nickel occurs in meteoric masses.

*Iron and Cobalt* produce alloys similar to those of nickel. The effect of the cobalt is to render the iron red-short.

*Iron and Silver* do not alloy well together. The alloy seems homogeneous when fluid, but the silver separates after cooling. Silver tends to render malleable iron red-short.

*Iron with Gold and Platinum.*—These metals alloy well together, small quantities of iron added to gold increasing its hardness. With platinum and steel an alloy may be obtained that is fusible at a temperature considerably below that required to melt steel; and, with 1 per cent. of platinum, steel yields a tenacious and fine-grained product.

*Lead Alloys.*—Lead is alloyed with antimony in the manufacture of type-metal; see *Antimony Alloys.* Combined with arsenic, it is employed for shot-making; see *Arsenic Alloys.* Lead in very small proportions suffices to impair the ductility of copper both at ordinary temperatures and at a red heat. For pewter, solders, etc., see *Tin Alloys;* also SOLDERING. Lead enters into fusible alloys, for which see *Bismuth Alloys.* The alloys of lead and silver separate when slowly cooled from fusion. Practical application of this quality is afforded in the Patinson process for the separation or concentration of silver, in the treatment of argentiferous lead.

*Manganese Alloys.*—See *Iron* and *Manganese*, under *Iron Alloys.* Manganese bronze is formed by the addition of from 1 to 2 per cent. of manganese to the proper proportions of copper and zinc, for the making of either bronze or brass. It is very homogeneous and close-grained, even a good-sized ingot broken through presenting a fracture as fine and close-grained as a piece of steel; the metal also possesses increased strength, toughness, and hardness, which latter quality can be increased very considerably. In color it resembles good gun-metal, but is of a rather brighter and more golden hue. It can be forged at a red heat and rolled into rods or sheets, and drawn into wire and tubes.

It is about equal in tensile strength and elongation to wrought-iron of average good quality, while its elastic limit is rather higher; for scarcely any wrought-iron will exceed 10 or 11 tons. A number of forged specimens which have been tested considerably exceed the very best wrought-iron both in tensile strength and ultimate elongation, and are fully equal to mild qualities of steel.

*Mercury Amalgams.*—The bodies resulting from the union of mercury with another metal are called amalgams. They include amalgams of mercury and tin, for silvering of mirrors; of mercury with gold and tin, employed in gilding; and with tin, gold, and silver, used in dentistry. 30 parts of mercury to 1 part sodium forms a compound liquid at moderate heat, but at the ordinary temperature yields a granular, tolerably hard solid, which may be filed into a powder; while with 1 per cent. of sodium it is viscid, and consists of a solid and liquid portion. This amalgam is employed as a medium for effecting the amalgamation of iron, platinum, etc.; it is also used to facilitate the amalgamation of gold and silver. An amalgam of zinc with 20 per cent. mercury is used for coating the rubbers of electrical machines.

*Molybdenum Alloys.*—Berthier states that an alloy of tin 83, molybdenum 7 (or 17?), is as white, ductile, and tenacious, as tin, and may be laminated into thin sheets. An alloy of molybdenum with lead whitens the color of the lead, if the proportion of molybdenum is not over one-twentieth; above that, lead becomes harder and darker.

*Platinum Alloys.*—The alloy of platinum, iridium, and rhodium, is harder and withstands a higher heat than pure platinum, and for that reason is better adapted for making crucibles. Alloys of platinum and iridium have a greater density in proportion to the amount of iridium present. With 90 per cent. of platinum and 10 of iridium, the density is 21.6; it reaches 22.38 if the iridium forms 95 per cent. of the whole.

*Rhodium Alloys.*—According to Messrs. Scott and Faraday, alloys of steel holding from 1 to 2 per cent. of rhodium present very great tenacity united to such hardness, that the cutting-instruments made with these alloys could bear a tempering-heat 30° Fahr. above that of the best Indian wootz, although the tempering-point of the latter is 40° above that of the best English cast-steel. Equal parts of steel and rhodium yield a fusible alloy well adapted for the manufacture of metallic mirrors.

*Nickel Alloys.*—Nickel is principally used together with copper and zinc, in alloys that are rendered the harder and whiter the more nickel they contain; they are known under the names of albata, British plate, electrum, German silver, pakfong, teutanag, etc. The proportions differ much, according to price; thus the

Commonest are 3 to 4 parts nickel, 20 copper, and 16 zinc.
Best are 5 to 6 parts nickel, 20 copper, and 8 to 10 zinc.

About two-thirds of this metal is used for articles resembling plated goods, and some of which are also plated (see *Silver*); the remainder is employed for harness, furniture, drawing and mathematical instruments, spectacles, the tongues for accordions, and numerous other small works.

The *White Copper* of the Chinese, which is the same as the German silver of the present day, is composed, according to the analysis of Dr. Fyfe, of

31.6 parts of nickel, 40.4 of copper, 25.4 of zinc, and 2.6 of iron.
17.48 " " 53.39 " 13.0 " *Frick's Imitative Silver.*

The white copper manufactured at Sutil, in the duchy of Saxe-Hildburghausen, is said by Keferstein to consist of copper, 88.000; nickel, 8.753; sulphur, with a little antimony, 0.750; silex, clay, and iron, 1.75. The iron is considered to be accidentally introduced into these several alloys, along with the nickel, and a minute quantity is not prejudicial.

Iron and steel have been alloyed with nickel; the former (the same as the meteoric iron, which always contains nickel) is little disposed to rust, whereas the alloy of steel with nickel is worse in that respect than steel not alloyed.

*Palladium Alloys.*—These are all harder than the pure metal. With silver it forms a very tough malleable alloy, fit for the graduations of mathematical instruments, and for dental surgery, for which it is much used by the French. With silver and copper, palladium makes a very springy alloy, used for the points of pencil-cases, inoculating lancets, tooth-picks, or any purpose where elasticity

and the property of not tarnishing are required; thus alloyed, it takes a high polish. Pure palladium is not fusible at ordinary temperatures, but at a high temperature it agglutinates so as to be afterward malleable and ductile.

Palladium and silver combine in almost all proportions, making alloys which have been used for scales on philosophical instruments.

*Silver Alloys.*—English standard silver consists of $11\frac{2}{20}$ pure silver and $\frac{18}{20}$ copper, or 11.10 silver and 0.90 copper. A pound of troy, therefore, is composed of 11 oz. 2 dwts. pure silver and 18 dwts. of copper. Its density is 10.3; its calculated density is 10.5, so that the metals dilate a little on combining. The French silver coin is constituted of 9 silver and 1 copper. (*Brande.*) The French *billon* coin is 1 silver and 4 copper. (*Kelly.*)

"For *silver plate*, the French proportions are $9\frac{1}{2}$ parts silver, $\frac{1}{2}$ copper; and for trinkets, 8 parts silver, 2 copper."

Silver solders are made in the following proportions:

Hardest silver solder: 4 parts fine silver and 1 part copper. This is difficult to fuse, but is occasionally employed for figures.

Hard silver solder: 3 parts sterling silver and 1 part brass wire, which is added when the silver is melted, to avoid wasting the zinc.

Soft silver solder, for general use: 2 parts fine silver and 1 part brass wire. By some few, three-fourths part of arsenic is added, to render the solder more fusible and white, but it becomes less malleable. The arsenic must be introduced at the last moment, with care to avoid its fumes.

Silver is also soldered with tin solder (2 tin, 1 lead), and with pure tin.

Silver and mercury are used in the plastic metallic stopping for teeth.

When heated in a muffle, the alloys of silver and copper are superficially oxidized, presenting various colored films on the surface. Thus, pure silver with 50 parts of copper per 1,000 silver becomes dull grayish-white; with 100 parts of copper per 1,000, it assumes a dull grayish-white color with black fringes along the edges; while with 120 to 140 parts copper the alloy becomes gray, and almost black. If the copper reaches 160 parts per 1,000, the alloy becomes entirely black. Doppler's reflector-metal has a bluish-white color, and contains 4 parts of silver to 1 of zinc.

*Tin Alloys.*—Tin imparts hardness, whiteness, and fusibility to many alloys, and is the basis of different solders, pewters, Britannia metal, and other important alloys, all of which have a low power of conducting heat.

Pewter is principally tin; mostly lead is the only addition, at other times copper, but antimony, zinc, etc., are used with the above, as will be separately adverted to. The exact proportions are unknown even to those engaged in the manufacture of pewter, as it is found to be the better mixed when it contains a considerable portion of old metal, to which new metal is added by trial.

Generally, however, pewter consists of lead 80 and tin 20 parts, to which other metals are often added. Some pewters, when cast, are black, shining, and soft; when turned, dull and bluish. Other pewters only contain one-fifth or one-sixth of lead; these, when cast, are white, without gloss, and hard; such are pronounced very good metal, and are but little darker than tin. The French Legislature sanctions the employment of 18 per cent. of lead with 82 of tin, as quite harmless in vessels for wine and vinegar.

The finest pewter, frequently called "tin and temper," consists mostly of tin, with a very little copper, which makes it hard and somewhat sonorous, but the pewter becomes brown-colored when the copper is in excess. The copper is melted, and twice its weight of tin is added to it, and from about one-half to 7 lbs. of this alloy, or the "temper," are added to every block of tin weighing from 360 to 390 lbs.

Antimony is said to harden tin and to preserve a more silvery color, but is little used in pewter. Zinc is employed to cleanse the metal, rather than as an ingredient. Some stir the fluid pewter with a thin strip, half zinc and half tin; others allow a small lump of zinc to float on the surface of the fluid metal while they are casting, to lessen the oxidation.

Coarse plumbers' solder contains lead 2 to tin 1 part; common solder is formed of equal parts of the two metals and fine solder has 2 parts of tin to 1 of lead.

*Zinc Alloys.*—The principal zinc alloys have already been referred to in connection with the alloys of copper, tin, and lead, which see. In alloys where zinc is a component part, it is best to melt the zinc in a separate vessel, to pour the molten copper, etc., into the casting-ladle, and, after having covered the latter with a brasque, to let the zinc into the copper through an opening made in the brasque. When melted, zinc is quickly oxidized by air; and if the temperature is raised above that of fusion, it will volatilize rapidly, and its vapors will burn, producing a flaring white light and fumes.

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AMALGAMATING MACHINERY. Amalgamation is the process of extracting gold and silver from the gangues in which they occur in Nature by combining them with mercury. The ores are crushed, and then washed through different machines in which mercury is placed This seizes upon the little particles of the metals that come in contact with it, and brings them together into one mass, from which the earthy matters are all washed away. Any greasy substance present almost wholly prevents this effect, the grease adhering in a film upon the surface of the mercury, and thus rendering impracticable the close contact necessary for their union. The amalgam is from time to time taken out of the washing-machines, squeezed through cloth or dressed deerskin, the liquid portion replaced, and the solid distilled in an apparatus suitable for saving the mercury, which is then ready for use upon another lot of ore.

AMALGAMATION OF SILVER.—The various processes are as follows: The patio process, the hot process, the estufa process, the barrel process, and the pan process. In the patio process, the materials necessary for the reduction of the silver are magistral (a soluble sulphate of copper produced from copper pyrites), common salt, and mercury. The ore is ground to powder and mixed with water to a mud. It is then placed in walled receivers called "lameros," where it parts with a portion of its water, and accumulates until it becomes sufficient to form a "torta." This is then spread out to the thickness of about a foot and tramped by animals, magistral and salt being afterward added, and finally the mercury. Repeated treading follows, until the mercury has absorbed all the silver, when the mass is washed by agitation in a series of tanks in which are rapidly revolving stirrers. The rate of motion of these is gradually reduced, and the metallic or heavier particles sink. The earthy portions in suspension are drawn off, and the amalgam and heavier mineral particles are separated by subsequent washing. A portion of the mercury is then strained out, and the remaining amalgam is formed into bricks and retorted.

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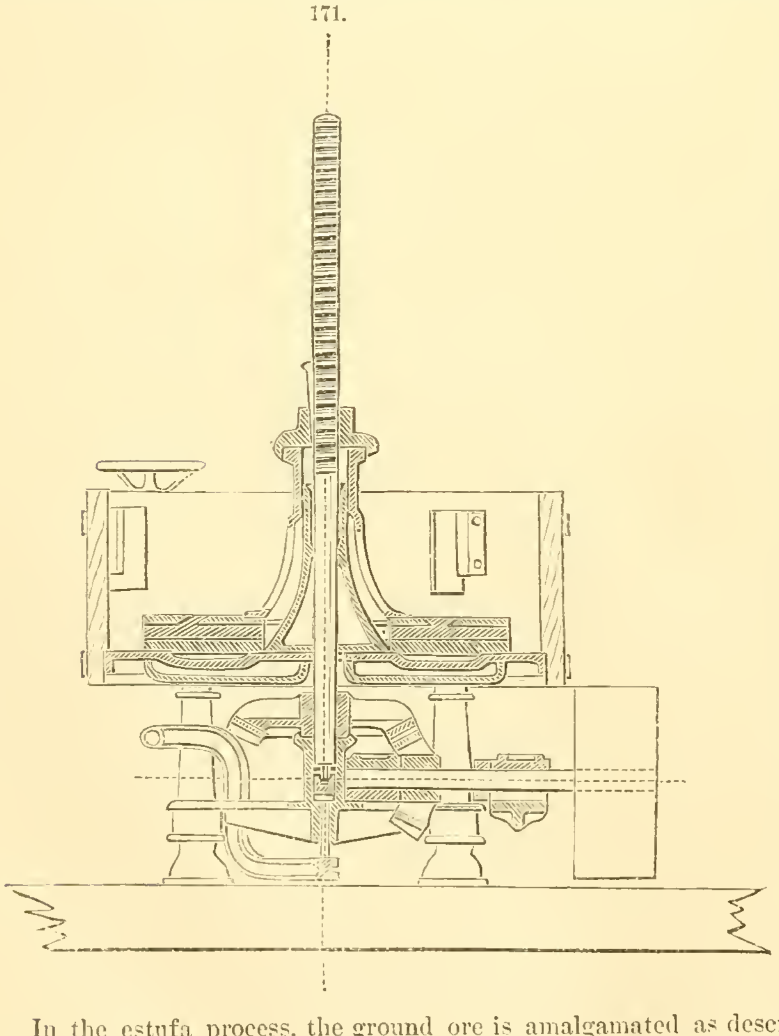

The hot process is chiefly employed in South America on a peculiar class of ores, containing a large proportion of native silver ore, in which that metal occurs in the form of chloride, iodide, or bromide. The ore is stamped and washed, and the richer portion condensed. The latter is placed in a *cazo*, or copper-bottomed vessel, over a furnace; water is added to make it into a paste, and subsequently the salt and mercury are introduced. The operation completed, the liquid matter is removed and added to the ingredients of a "torta," while the solid portions are stored in wooden cisterns, and are subsequently washed and treated as described under the patio process.

In the estufa process, the ground ore is amalgamated as described by patio amalgamation until the process is about half completed. It is then removed into a chamber termed an *estufa* (stove), which has under it a fireplace 6 or 8 feet in length, so connected by side-flues with small chimneys

as to elevate the temperature of the room containing the ore. Here it is exposed to a gentle heat, and allowed to remain two or three days, when it is again removed, and the reduction completed by the ordinary method of patio amalgamation.

In the barrel process, the ores are dried in a kiln, dry-stamped, screened, and roasted in reverberatory furnaces, salt and carbonate of soda being added. The roasted ore is then screened and placed with iron fragments, mercury, and water in revolving barrels. The amalgam is strained through a canvas bag to remove a portion of the quicksilver, and is distilled in circular retorts.

The pan process dispenses with the roasting incident to the barrel process, and with the frequent manipulations and loss of time incident to the patio process. A large number of pans and amalgamators have been devised, all, however, being similar in their action. The grinding in all is effected between two opposing plates of iron, and the chief differences between them consist in the modification of the form of these plates and the extent of their surface. They all combine the qualities of a mill with the capacity to hold a certain amount of ore-pulp, for it is not simply grinding that is required; the operation of amalgamation and chemical reduction of the ores is connected with it. Inasmuch as the constant grinding would soon cut through the thin bottoms of the pans if unprotected, and destroy the mullers, false bottoms or dies are cast for the pans, and face-plates (shoes) of hard white iron for the mullers. These are so made as to be easily taken out, and are renewed when worn out. In general, the pans are not intended to receive and grind coarse materials, though in some of them ore as large as kernels of corn, or even larger, can be ground to a fine powder without much injury to the pan. In practice it is the battery-pulp and sand which are fed, and this is generally done in charges (or "batches"), the weight of which depends upon the capacity of the pan. They are first ground, and then, with the addition of quicksilver, and at a lower rate of speed, the amalgamation is effected. The charge is then drawn off into a larger pan, fitted with stirrers, called the separator. In this the pulp is much diluted with water, and the quicksilver and amalgam fall to the bottom and are collected.

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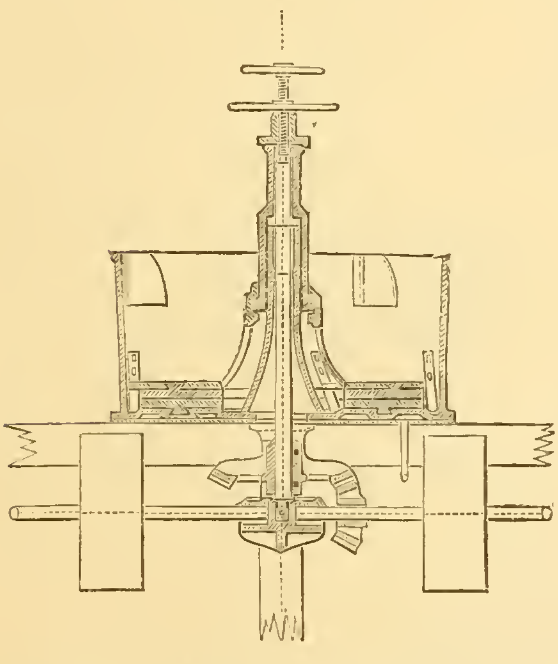

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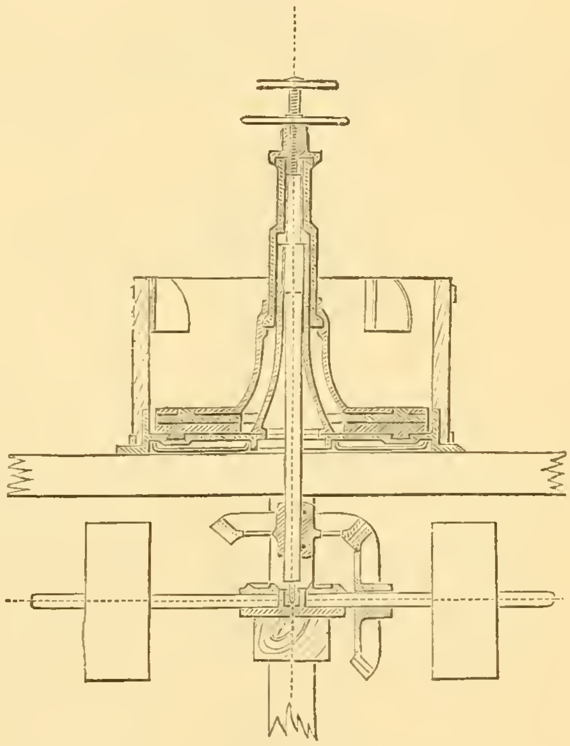


*Pans.*—The principal pans and amalgamators may be grouped in two chief divisions: 1. Those with flat bottoms; 2. Those with curved or conoidal bottoms.

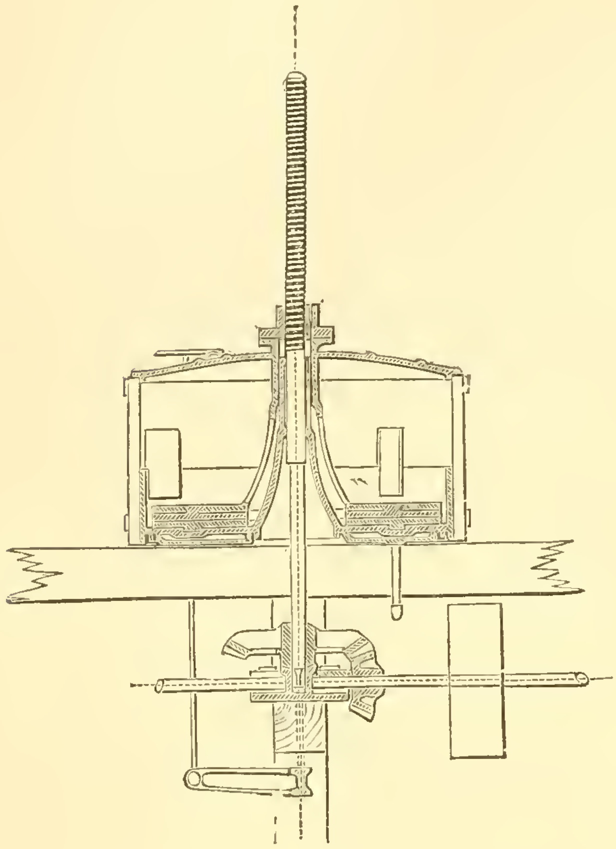
The Wheeler pan, Fig. 171, is made with a flat bottom, to which the dies are secured by dovetailed tongues and sockets. The shoes are attached to the muller-plate in similar way. The muller is carried by a vertical shaft passing up through the cone in the middle of the pan, and is raised up for the purpose of cleaning the pan by a screw cut on the shaft. The regulation of the distance of the shoe and die from one another in working is accomplished by a hand-wheel at the side of the pan, which through a lever raises or lowers the steel block into which the toe of the upright shaft steps. Bevel-gearing transmits the motion of the vertical shaft from the horizontal shaft, which has a pulley on its outer end.

The Horn pan, Fig. 172, has, like the Wheeler, a flat bottom. The body of the pan is set directly upon the plate which serves both as foundation and as steam-bottom, and the joint is made with cement. The shoes and dies are secured by dovetailed tongues and sockets. A groove runs around the pan, outside the circumference of the muller, which is traversed by a scraper, fastened to the muller. The gutter around the cone is also scraped in the same way. The muller is hung loose upon the driver, which is carried by the vertical shaft, and is regulated as to height by the screw at the top, the point of which rests upon the top of the shaft. A yoke is fastened to the bottom of the pan, which serves for a foot-step, and also carries the bearing for the horizontal-motion shaft.

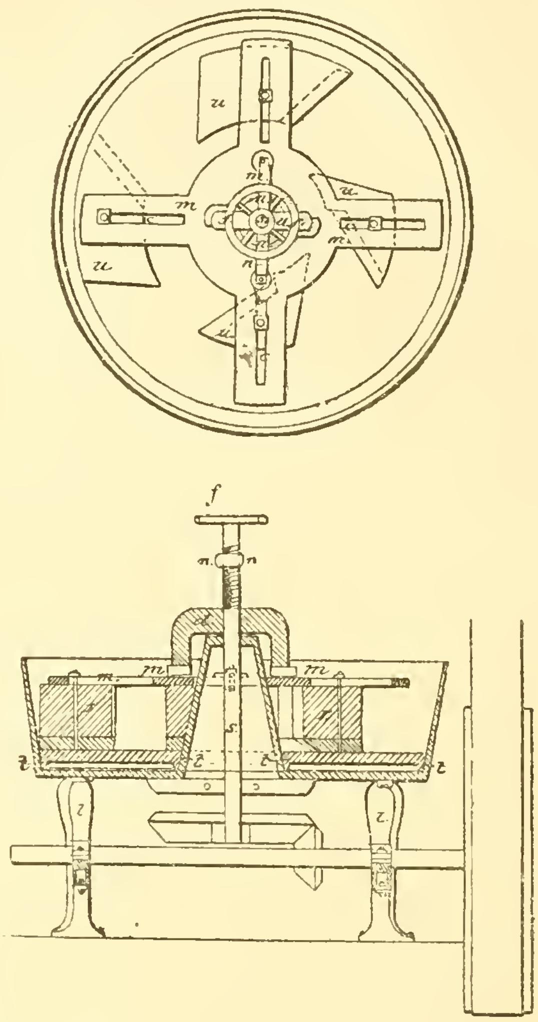
The Patton pan, Fig. 173, is a combination of the two pans above described. The steam-bottom is fastened beneath, as in the Wheeler pan; and the yoke, which in the Horn pan serves for a foot-

step, and also carries the bearing for the horizontal shaft, is here dispensed with, the foot-step and shaft-bearing being set upon the wooden framing of the mill which carries the pans. The manner of hanging the muller loose upon the driver, which is carried by a vertical shaft and regulated in height

174.



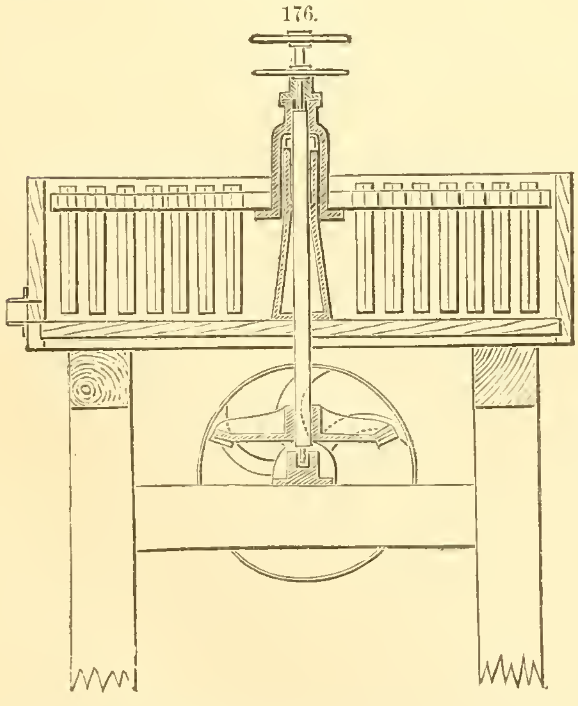
175.



by a screw at the top, is the same as in the Horn pan; and the attachment of the dies to the bottom, and of the shoes to the muller, by means of dove-tailed tongues and sockets, is the same as in both the Wheeler and the Horn pans; but in the Patton pan the sides are of wood. The curved flanges shown extending inward from the upper part of the side are intended to effect a circulation of the pulp.

The combination pan, Fig. 174, is the Patton pan with the Wheeler foot-step, its chief feature being a cast-iron ring set in the pan to protect the wooden sides. This ring can be replaced when worn.

176.



The Knox pan, Fig. 175, is of cast-iron, and has a false bottom with projecting vertical rim at the periphery to form a hollow annular space underneath for the introduction of steam. There is also a radial groove in the false bottom for the accumulation of quicksilver and amalgam, connecting with the lower discharge-hole situated opposite the driving-shaft. The centre of the yoke $d$, attached to the muller $m$, is keyed to a vertical wrought-iron shaft $s$, guided by a cast-iron hollow cone in the middle of the pan. The muller $m$ is a flat cast-iron ring, attached to which are four arms at right angles to one another, and to these the cast-iron shoes $a$ are bolted through slits $c$. Between the muller and shoe a wooden shoe $r$, of the exact shape of the iron one, is introduced to prevent the settling of the unground pulp in the latter, the upper face of the wooden shoe reaching above the surface of the pulp.

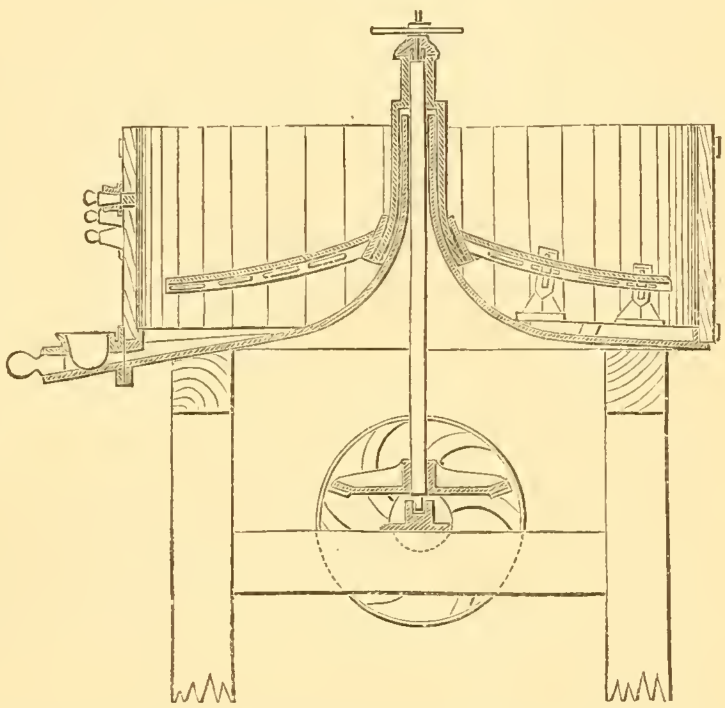
*The Agitator.*—The battery-slimes, after being amalgamated in the pan and the amalgam collected in the settler, are run to a third receptacle resembling the pan and settler, but of larger dimensions and with different working apparatus. Some kinds of amalgam, such as those containing copper or antimony, are friable, and on account of their fineness cannot be recovered from the pulp while it is thick. It is, therefore, run into a circular tank or tub in which wooden stirrers revolve, a copious stream of water running constantly

in at the top. Here the pulp is thoroughly beaten up and thinned, and while the lighter parts flow off with the current, the amalgam and floured mercury fall to the bottom and collect there. This amalgam is always both poorer and less pure than that from the settler.

Fig. 176 shows one of H. J. Booth & Company's agitators. It is formed of a round tub, the bottom and sides of which are made of wood. In the centre a hollow cast-iron cone is bolted, through which rises the shaft, driven by a cog-wheel below. A cast-iron cap or carrier rests on the top of the shaft, and from this project iron arms, in which are fastened the wooden stirrers, hanging vertically and reaching down nearly to the bottom of the tub.

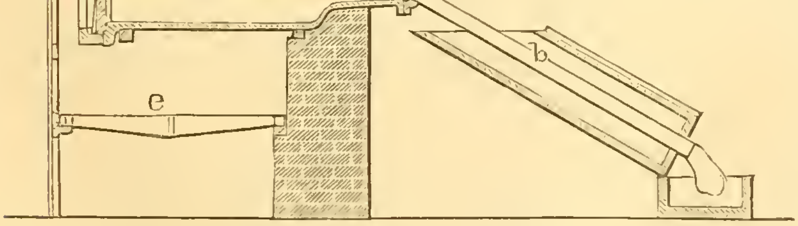
*The Settler.*—The work of the settler, Fig. 177, in the system of amalgamation, is to separate the minute particles of mercury and amalgam from the pulp through which they are distributed. It resembles a pan in some respects, being made up of a circular box, in which revolves a central axis carrying arms, and to these arms are fixed shoes. These iron shoes, however, do not come in contact with the bottom of the settler, as no grinding action is desired. They are faced with wooden rubbers, which keep the heavier parts of the pulp thoroughly stirred up, while the revolving arms perform a similar service for the lighter portions floating above. The pulp is thinned by a stream of water during the operation, for which reason the settler has a larger capacity than the pan. It is formed of a conoidal iron casting, in the hollow axis of which works the upright to which the revolving arms are fastened. The sides of the settler are of wood, but sometimes sheet-iron is used instead. Holes stopped by plugs are pierced in the sides at different levels, through which the thinned pulp can be gradually drawn off. On one side is bolted an iron quicksilver bowl, communicating with a radial gutter cast in the iron bottom. The rotary part of the apparatus consists of the central shaft before mentioned, which carries on its lower end a beveled cog-wheel, and at its upper end an arrangement for adjusting the height of the wooden rubbers, so as to lower them as they gradually wear away. This arrangement consists in a deep collar embracing the vertical part of the conoidal iron bottom of the settler, and hung upon the shaft by a screw furnished with a hand-wheel. The revolving arms are carried out from this collar.

177.



*Retorts for Amalgams.*—The silver retort is as well adapted for the retorting of gold as of silver amalgam, when the quantity is sufficiently large to render it desirable. The silver retort shown at *a* in Fig. 178 is commonly made 12 inches in diameter inside, with a hood at the mouth having lugs to catch the clamp which fastens the door. The whole retort is set on cast-iron bearers in an arch, with the fire-grate under it. The neck of the retort passes through the back wall, and connects with the condenser. The condensed quicksilver filters through a bag fastened on the end of the pipe, and is received into a tray.

178.



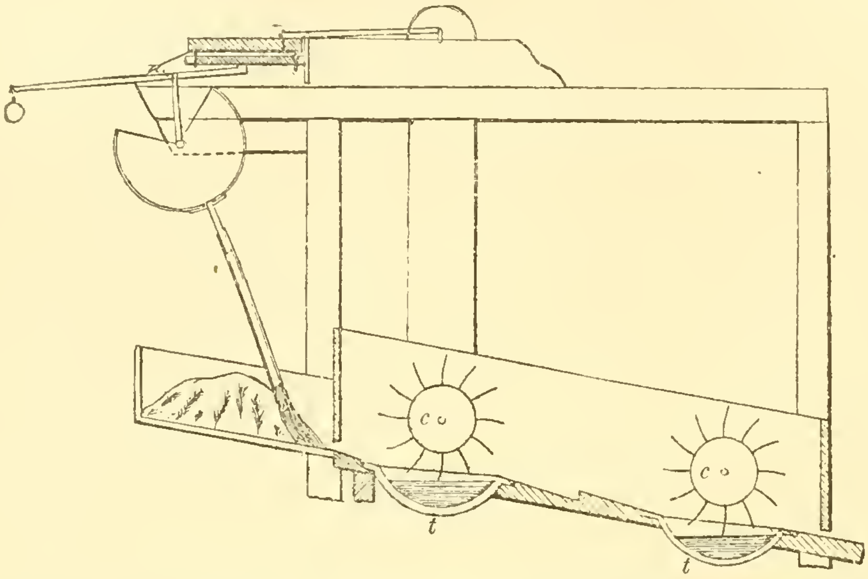

Amalgamation of Gold.—Two distinct systems of gold amalgamation are in use in California, namely, amalgamation in the battery, and amalgamation in special appliances after the gold has been previously crushed. In amalgamating in the battery, the latter is often provided with amalgamated copper plates extending the whole length of the box, one on the feed side and the other on the discharge, and each having an inclination of from 40° to 45° toward the stampers. When these are not employed, spaces for the accumulation of amalgam are allowed between the dies and sides of the box, and vertical iron bars are placed inside the gratings, between which the hard amalgam is found to collect. The copper plates are covered with mercury, and the latter is also sprinkled into the boxes by the feeder. One ounce of gold requires for its collection about an ounce of mercury.

When the rock is crushed without the introduction of silver into the mill, the sand and water issuing from the latter are conducted over blankets spread on the bottoms and lining the sides of shallow troughs and sluices inclined at an angle of from 3° to 4° with the horizon. Beyond these blankets there are in most cases riffles or amalgamated copper plates, which are again followed by

some contrivance for collecting the pyrites remaining in the tailings. At the further extremity of this system of appliances there is sometimes a long tail-sluice for the purpose of arresting any auriferous material which may have escaped being caught by the other arrangements.

The blanket washings are introduced into a box in front of the amalgamators, one of which, the invention of Mr. M. A. Atwood, is represented in Fig. 179. This consists of two hollow cylindrical

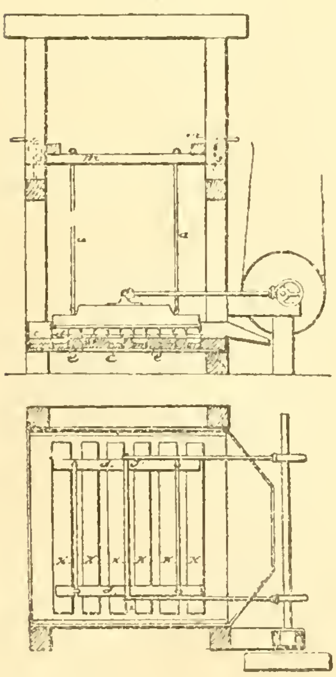
179.




troughs $t$ $t$, of wood or iron, which are filled with pure quicksilver. Over these the blanket washings are directed. The gold, being specifically heavier than the quicksilver, will sink to the bottom, with the exception of that part which is attached to the quartz or sulphuret, and is consequently buoyed up. The floating skimmings are agitated by wooden cylinders $c$, suspended parallel to and over the centre lines of the trough, and provided with radial arms of iron,the ends of which are slightly curved. These arms are set along the cylinders in 12 longitudinal rows, containing alternately 8 and 9 arms, those of each row being set opposite the spaces in the next. They are not allowed to dip into the quicksilver, but almost touch. These cylinders make 60 revolutions per minute.

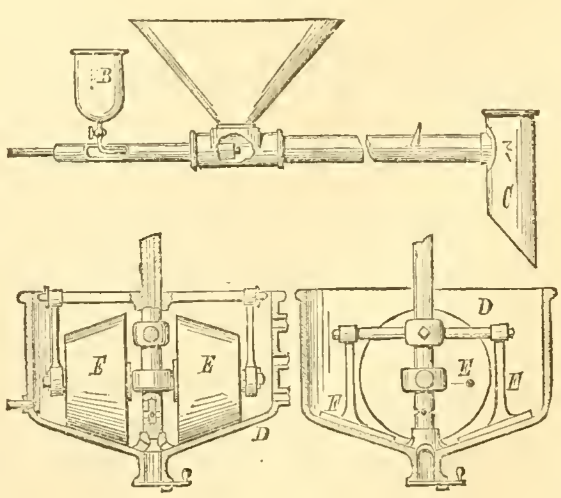
*The Rubber.*—The sands, after passing from the amalgamators, may be discharged into Eureka rubbers, in which the particles of gold are intended to be further cleaned and brightened by rubbing and detached from the sands, while they have an opportunity at the same time to be caught on the amalgamated copper plates of the rubber. The Eureka rubber, Fig. 180, consists of a rectangular cast-iron box, 7 inches deep and 4 feet 8 inches square, provided with a false bottom of cast-iron dies or plates, on which cast-iron shoes, fastened to a wooden frame, receive a rectilinear motion by rods connected with an eccentric. The wooden shoe-boards are covered with amalgamated copper plate.

180.



In the *Forster and Firmin system of amalgamation* the pulverized ore containing free gold or silver is fed from the hopper, shown in Fig. 181, with a horizontal tube $A$. While in the act of falling it is impinged upon by a stream of mercury, which escapes from the re-

181.




ceptacle $B$ through the inner pipe shown. The flow is broken up and carried forward by steam or air pressure, after the manner of the well-known principle of the sand-blast. The horizontal tube connects with a vertical tube $C$, upon which the ore and the atomized mercury are together forcibly projected, grain by grain, in a continuous stream, and fall by their own gravity into the

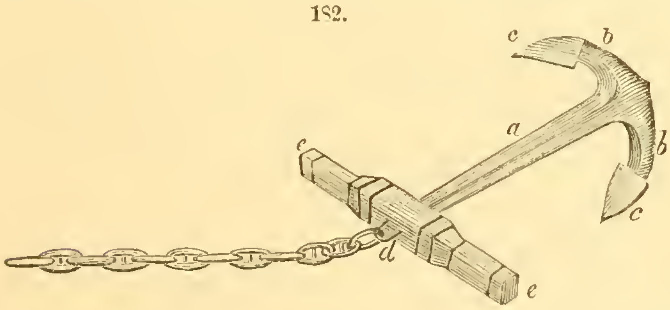
washer or receiver *D*. It is claimed that an almost unlimited quantity of ore may be treated by this process, as the attendants have only to feed the hoppers and remove the deposit. The inventors state that "with only a three-inch tube from three to five tons of ore can be treated per hour." In connection with this amalgamator an improved washer, shown in detail in Fig. 181, is used. This consists of a vessel having a conical bottom, in which rollers *E*, and also with scrapers or mullers *F*, are placed. The feed-water is injected through the shaft or near the bottom of the vessel, and the upward current carries off the waste ore, while the amalgam and surplus mercury collect in the dead-water space in the conical bottom, whence they are drawn off through the discharge cock.

*Use of Sodium Amalgam.*—The extraction of gold by amalgamation has hitherto been often attended with difficulties, occasioned by the presence of compounds of sulphur, arsenic, antimony, bismuth, or tellurium in the ores, which by covering the gold with a thin film of tarnish prevents its entering into combination with mercury. The use of sodium amalgam, discovered by Dr. Henry Wurtz of New York, is said not only to facilitate amalgamation under such circumstances, but also to prevent the "sickening" of mercury, which is apt to take place in the presence of certain chemical compounds (among others, sulphate of iron). It is also claimed that by its use the "flouring" of mercury when ground with compounds containing sulphur, arsenic, tellurium, etc., may to a great extent be avoided. See Phillips's "Mining and Metallurgy of Gold and Silver," London, 1867, p. 220.

*Miscellaneous Machines.*—A large number of special contrivances for separating and amalgamating purposes have been patented, none of which have come into very extended use. Many of them will be found fully illustrated and described in the article "Amalgamator" in Knight's "Mechanical Dictionary."

ANCHOR. A heavy curved instrument, used for retaining ships in a required position. The forms of anchors, and the materials of which they are made, are various. In many parts of the East Indies the lower part of the anchor is formed of a cross of a very strong and heavy kind of wood, the extremities of which are made pointed. About the middle of each arm of the cross is inserted a long bar of the same wood, the upper ends of which converge to a point, and are secured either by ropes or an iron hoop, and the space between the bars is filled up with stones, to make the anchors sink more deeply and readily. In Spain, and in the South Seas, anchors are sometimes formed of copper, but generally in Europe they are made of forged iron. Anchors may be divided into two classes: mooring anchors and ships' anchors. Mooring anchors are those which are laid down for a permanency in docks and harbors, and are considerably heavier than ships' anchors, from which they differ in form, having sometimes but one arm, and sometimes, instead of arms, having at the extremity a heavy circular mass of iron and no stock: these latter are called mushroom-anchors. The general form of ships' anchors is shown in the annexed figure. There is a long bar of iron *a*, called the shank, from the lower extremity of which branch two curved arms *b b* in opposite directions, and forming an angle of 60° each with the shank. Upon each arm, toward the end, is laid a thick triangular piece of iron *c c*, termed the *fluke*. In the upper end of the shank is an eye, through which passes a ring *d*, to which the cable is attached. The stock *e e* is composed of two strong beams of wood, embracing the shank, or an iron rod passing through the shank. The stock stands at right angles to the plane of the arms, and serves to guide the anchor in its descent, so as to cause one of the flukes to enter the ground. Ships are generally provided with three large anchors, named the best bower, the small, and the sheet anchor; a smaller anchor, termed the stream-anchor; and another, still smaller, named the kedge, which latter has generally an iron stock passing through an eye in the shank, secured thereto by a key, or forelock, which admits of its being readily displaced: its principal use is in changing the position of a ship in harbor, and in an operation termed kedging. From the great mass of iron in large anchors (some weighing from 3 to 4 tons), the perfect forging of them becomes a matter of much difficulty; as, from the great heat necessary to weld such masses, the iron is liable to become "burnt," as it is termed. The strength of anchors is tested by means of the hydrostatic press. The proof-strains are as follows:

182.




| Weight of Anchor in Cwt. | Strain, Tons. | Weight of Anchor in Cwt. | Strain, Tons. |
|---|---|---|---|
| 100 | 67 | 40 | 35 |
| 90 | 63 | 30 | 28 |
| 80 | 58 | 20 | 20 |
| 70 | 53 | 10 | 12 |
| 60 | 48 | 5 | 7 |
| 50 | 42 | 1 | 3 |

The following proportions may be used in designing anchors: Length of shank, 100; of each arm from crown to bill, 40; of stock, 100; radius for describing outside curve of arms, 35; angle of face of palm with shank, 57°. With such proportions the angle of the shank with the ground is 24°, and that of blade 75°. In devising a new anchor, the danger of the ship's grounding upon it is a most important consideration. As a rule, the stocks of anchors weighing more than 60 cwt. are of wood.

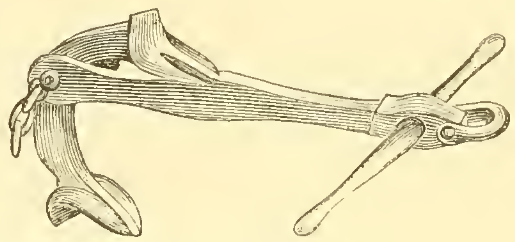
The following is a table of the approximate values of the properties essential to a good anchor: Strength, 45; holding, 30; quick holding, 15; canting, 15; facility of sweeping, 10; facility of stow-

ing, 10; exemption from fouling, 10; fishing, 10; facility of transportation in boats, 5; quick tripping, 5: total, 160.

The largest anchor now in existence was made for the Great Eastern. It weighs 8 tons exclusive of the stock, and the length of its shank is 20 feet 6 inches. It is somewhat different in form from ordinary anchors, the flukes being split so that the sea-bottom may be more readily pierced. The weight of the largest anchors for vessels of 1,000 tons or less bears usually the proportion of about .0025 the tonnage.

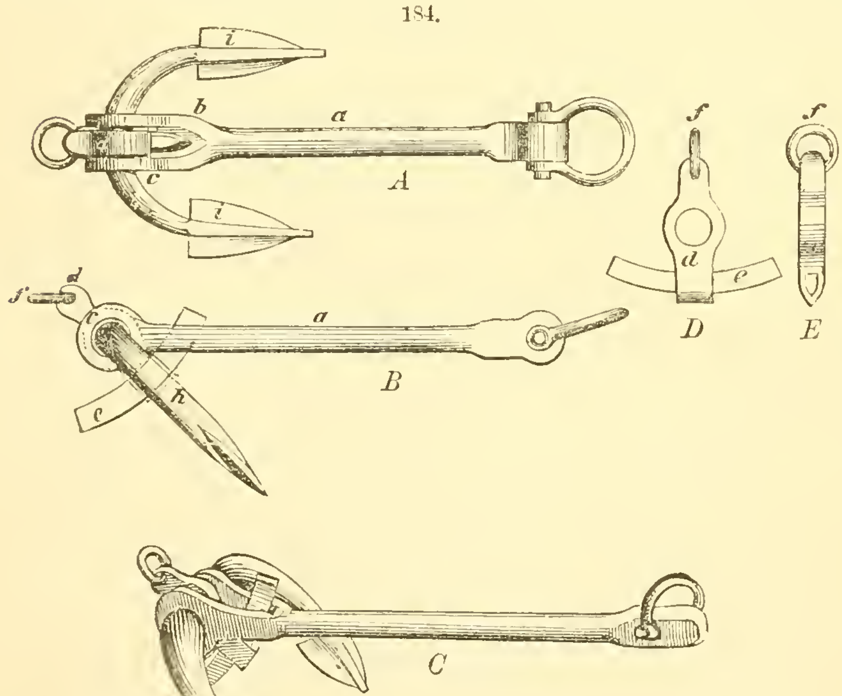
The form of anchor most commonly used in place of that represented in Fig. 182 is Trotman's, which is an improvement embodying some minor modifications on Porter's anchor, shown in Fig. 183.

183.

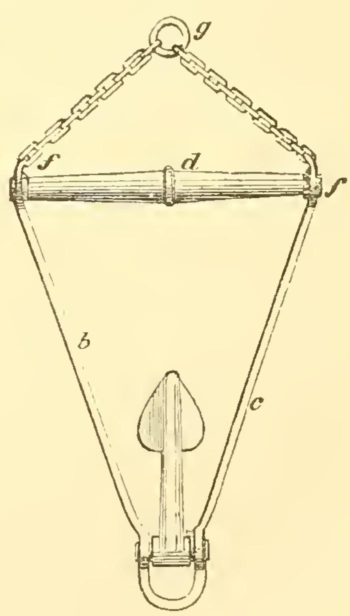


Hawkins's anchor, *A* to *E*, Fig. 184, has its shank *a* forked to form two loops *b* and *c*, in each of which is an eye. Between the loops is an iron block *d*, having a circular aperture to receive the arms, and a square aperture at right angles to the former, into which is screwed a stout bar of iron *e*, termed a toggle, projecting equally on each side of the crown-piece; on the end of the crown-piece, opposite to that in which is inserted the toggle, is a ring *f* for the buoy-rope. The arms *g h* are formed in one piece, and, before the palms *i i* are attached, one end of the arms must be passed through the eyes in the loops of the shanks and through the eye of the crown-piece; the palms are then to be put on, and must both lie in the same plane; after which the arms are to be curved in the same plane with the palms. The crown-piece is firmly keyed to the arms, and the toggle must be of such a length and form as to make it bear firmly against the forepart of the fork in the shank, so as to prevent the crown-piece and arms from turning round upon it, and to retain them at an angle of 50° with the shank. When the anchor is let go, one end of the toggle will come in contact with the ground, which puts the flukes in a position to enter; and when the strain is upon the cable, that end of the toggle which is upward comes in contact with the

184.



185.



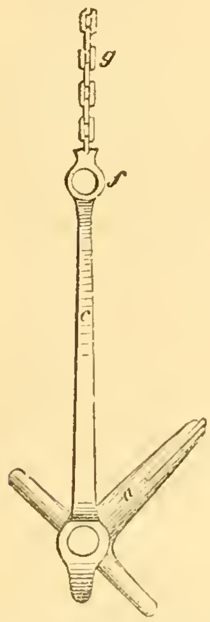
throat of the shank, and sets the anchor in the holding position, which is shown in perspective at *C*. The advantage of this mode of constructing anchors is, that both arms take the ground, and therefore the weight of metal may be diminished and yet an equal, if not a greater, effect be obtained; also, as there is no stock, and no projecting upper fluke, there is little risk of *fouling*, as it is termed—that is, of the cable entwining round the arms.

An anchor upon a similar principle, but of a somewhat different construction, was invented by Mr. Soames, a front and a side elevation of which are given in Figs. 185 and 186 respectively. In this anchor there is but one fluke *a*, which is T-shaped, and works on a pivot in a triangular frame, composed of the two sides *b* and *c*, forged in one piece, and a stay *d*, which serves as a stock; *f f* are loops, or eyes, for the reception of the chains that unite the ring *g*, to which the cable is to be fastened. For general purposes, this anchor is perhaps preferable to the former, it being free from the objection we made to that one, as it admits of detaching the arm, which renders it more convenient to stow away; also, as the shank is formed in two parts, instead of one of equal area, they are more easily forged soundly, and consequently less liable to breakage.

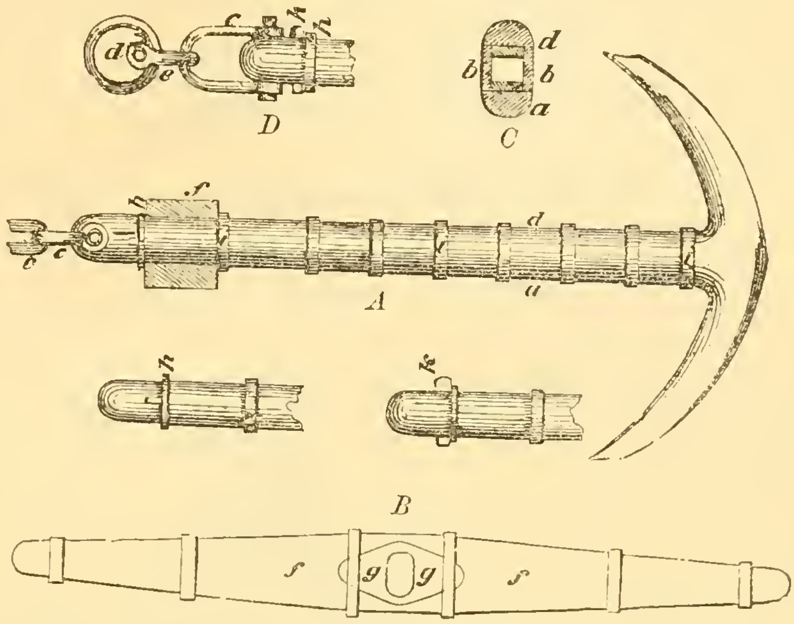
The peculiarity of the anchor proposed by W. Rogers consists in its having a hollow shank, formed

out of 6 bars of iron, of such thickness as to insure the forging of them perfectly sound for anchors of the largest dimensions. In Fig. 187, *A* represents a side-view of the anchor, and *B* a plan of the stock. The two principal pieces *a a* are bent so as to form a part of the arms or flukes; the other four are formed into a hollow tube *b b* (as shown in section at *C*) for a centre-piece, and the whole are firmly welded together at both ends of the shank. The intermediate parts are secured by strong hoops *i i*, so that every piece must bear its proportion of the entire strain. In place of the usual ring, there is a bolt and shackle *c*, employed alone when the anchor is to be used with

186.



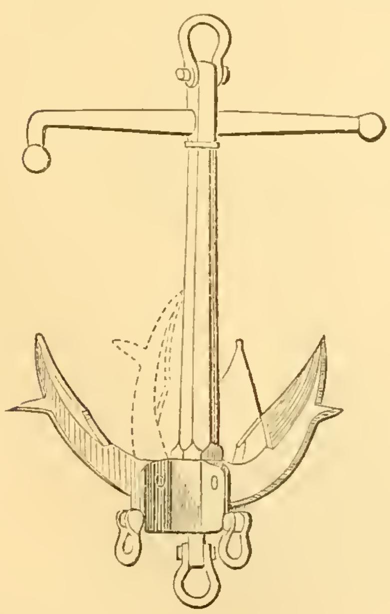

187.



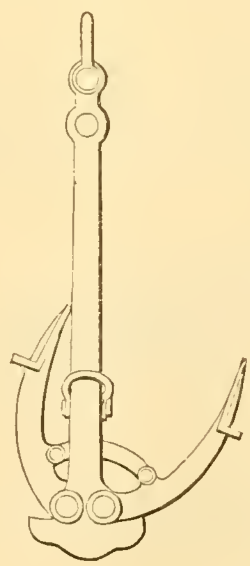

chain cables; but when hempen cables are to be used, a ring *d* is connected to the shackle *c* by an additional shackle and bolt *e*. The anchor-stock *f* may be formed either of a single piece, or of two pieces hooped together, and is secured in its place as follows: The bolt and shackle *c* being withdrawn, the small end of the shank is passed through the eye of the stock *f* (which is defended by an iron plate *g* on each side); the collar *h* is then put over, and the stock is keyed up against the hoop *i* by the forelock key *k* passing through a hole in the shank.

Williams's anchor, Fig. 188, has three flukes hinged to a block at the lower end of the shank, and so set that two of them may penetrate the ground simultaneously, while the third falls down upon the shank to prevent the fouling of the cable. The flukes are hinged to separate blocks, and are

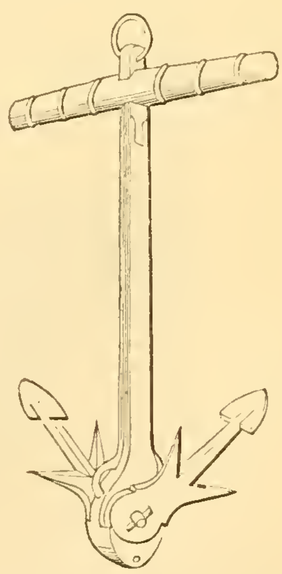
188.



188 A.



188 B.

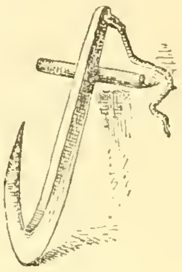


120° apart. Fig. 188 A represents Morgan's anchor, the arms of which are separately pivoted to the shank, and are connected by a curved bar passing through the latter. When one fluke has hold on the ground, its arm rests against and is supported by the crown-piece, while the other arm falls down upon the shank. Fouling is thus prevented, and the arms through the curved bar reënforce one another. Marshall's anchor, Fig. 188 B, has straight arms, moving separately on a pivot passing through the crown. The arms are barbed, and oscillation is checked by cusps on the thick portion of the crown, which hold the arms at a given inclination to the shank. Latham's anchor, Fig. 189, has its

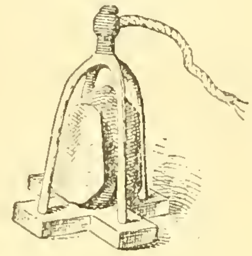
shank *A B* in two pieces, between which plays a middle fluke attached to an arm *C*, which has two other flukes on its ends. When the anchor is let go, the flukes make about a quarter of a revolution, lying in the position shown when they enter the ground. The shoulder on the crown-piece comes against the shank, and restrains the oscillation of the arms in either direction. This anchor may be very compactly stowed by bringing the arms parallel with the shank.

Two simple forms of anchor are represented in Figs. 190 and 190 A. Both are in use by fishermen the world over. In Fig. 190 A two stout pieces of wood are lashed or framed together crosswise; from the extremities rise wooden or iron rods, which inclose a large stone; the rods meet above,

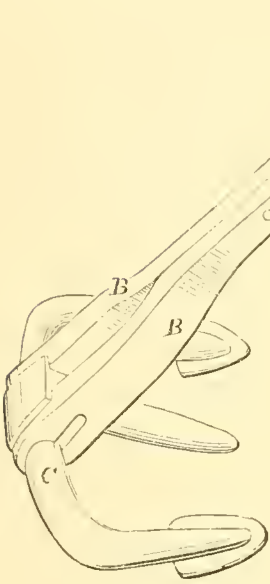
190.



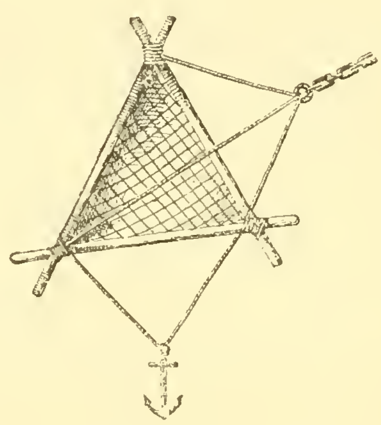
190 A.



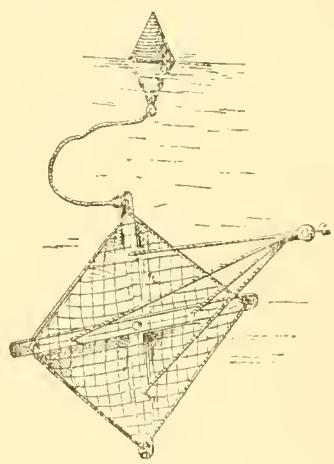
189.




190 B.



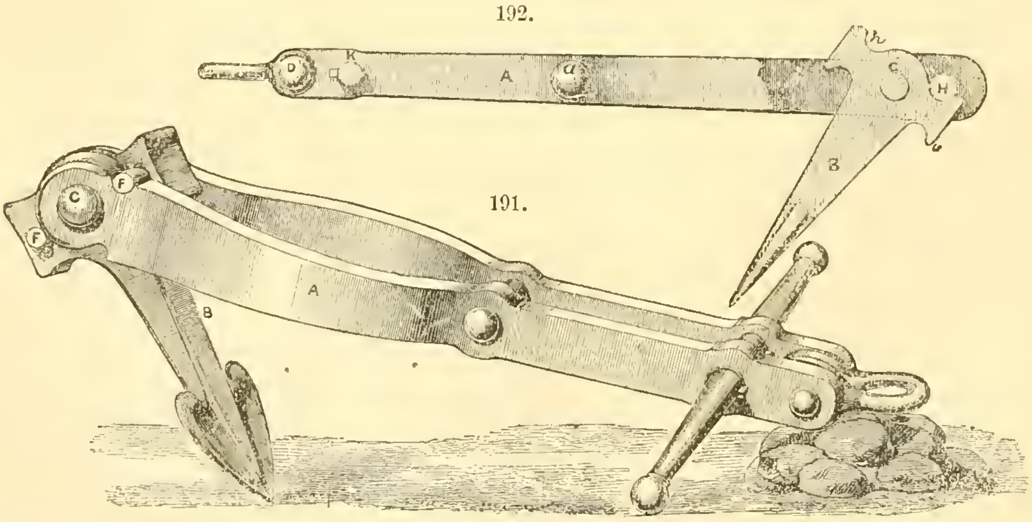
190 C.



and an eye is added for the attachment of the cable. Fig. 190 is simply a forked piece of wood, the long arm serving as a shank, the short one, which is barbed and shod with iron, as a single fluke. Sea-anchors are used by vessels when off soundings to prevent drifting, and to keep the ship's head to wind or sea. They are used during bad weather, and often enable vessels to ride out storms in which their safety might otherwise be endangered. The sea-anchor represented in Fig. 190 B consists of three spars lashed in the form of a triangle. Canvas is attached to the spars and backed by a strong

192.

191.

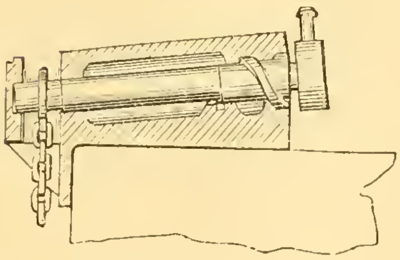


rope-netting. A kedge suspended from the base of the triangle, keeps it in vertical position, and three hawsers are attached to the angles and also to the ship's cable. The anchor in Fig. 190 C is made of two stout iron bars pivoted together at their middle and spread apart at right angles to each other. A rope is carried from end to end, and canvas and netting are spread on the frame thus formed. A buoy is fastened to the end of one of the bars, and prevents the sinking of the contrivance, while showing its position. The bars of which this anchor is formed may be folded parallel, thus admitting of the compact stowage of the device when not in use.

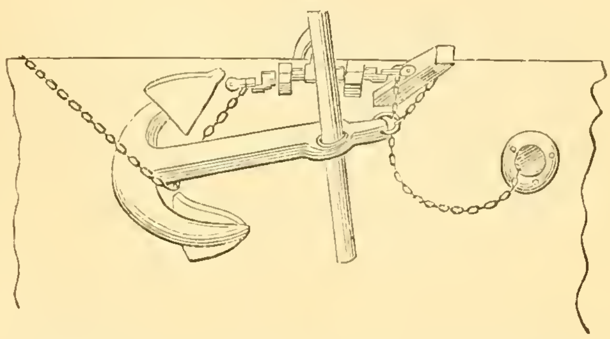
Tyzack's anchor is represented in Figs. 191 and 192. *A* is the shank made in two parts secured

to each other by the pins $H\ a\ K\ D$. The arm with its fluke $B$ is fitted with a T head $h\ g$, which bears on the pin $H$, as shown. Two pins $F\ F$ are fixed in the head, and act instead of the single pin $H$. The anchor has only one arm, which is reversible, and so arranged that, whichever way the anchor falls, it finds itself at once in a position to bite. The other chief advantages claimed are: that the anchor cannot foul when holding, having no projection above the shank; that it is very snug for handling; occupies a minimum space in stowing; can be readily taken to pieces; and pos-

193.



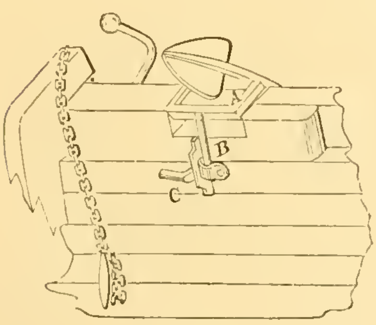
194.



sesses unusual strength, being made without a single weld. This anchor has been experimented with to test its biting and holding power, by dragging it over some rough ground by means of a powerful steam winch, when it was found that, immediately the steam winch caused the anchor to move, the arm at once penetrated the ground and buried itself immovably. An anchor of this type, weighing 6 tons 3 cwt. 5 qrs. exclusive of stock, has been subjected to the following strains, viz.: In the first instance to the Admiralty test, 9 tons 1 cwt. 1 qr.; then to 13, 17, 21, 25, 26; and finally to 32 tons, at which strain—250 per cent. overproof—it was broken to destruction.

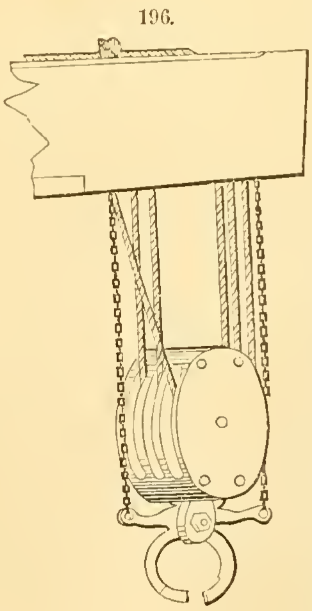
Anchor-trippers are devices for tripping or letting go an anchor, either after it is catted and fished or while it is hanging from the cat-falls. We give illustrations of five devices for tripping the anchor under the first-mentioned circumstances. In Holmes's tripper, Fig. 193, a short chain is attached to the ring of the anchor, and a large link on the end of said chain passes over a pin. The latter has a spiral thread which works in a nut in the bearing, so that, when the pin is turned, it recedes, and so frees the link. The shank-painter is similarly secured to a like device, and both pins must therefore be turned simultaneously to drop the anchor. In Heitman's tripper, Fig. 194, the anchor is suspended by shank-painter and ring-stopper. One end of each chain is fast to the vessel, while the rings at the other ends rest upon pivoted latch-pieces. These last are supported upon a bar, which is rotated by a lever to give simultaneous disengagement of the latches. In Gibson's tripper, Fig. 195, the fluke of the anchor rests on a block $A$, which is pivoted in a notch of the gunwale. A bar $B$ attached to said block is held by a shackle-bar $C$, when the latter is in its upper position. By sliding the shackle in its staple the bar is released, and the block $A$ is thus free to turn under the weight of the anchor. Duncan's device, Fig. 196, is for dropping the anchor from the cat-falls. The ring of the anchor is held in a clutch substituted for the usual cat-hook, which is automatically opened by the chains and levers shown as the tackle is slackened. In Stacy's device, Fig. 197, the hook is canted by a rope made fast to an eye in its rear portion, as the fall is paid out. As the hook upsets, the anchor, of course, slides off. In both Burton's and Spence's inventions the principle is the same. It consists in supporting the end of what is termed the standing part of the cat-head stopper and shank-painter by bolts turning upon pivots, and retained in a proper position by a catch, which being withdrawn, the bolt turns upon its pivot and the stopper slips off; by which means all risk of jamming the turns of the stopper (as in the common method of letting go the running end) is avoided, the danger to the men on the forecastle is done away, and the anchor can be let go at a moment's warning.

195.

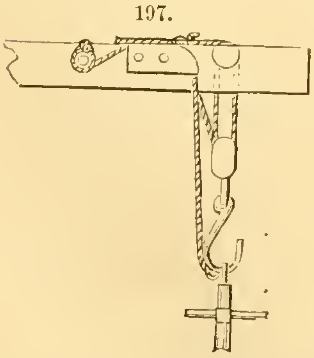




196.



197.

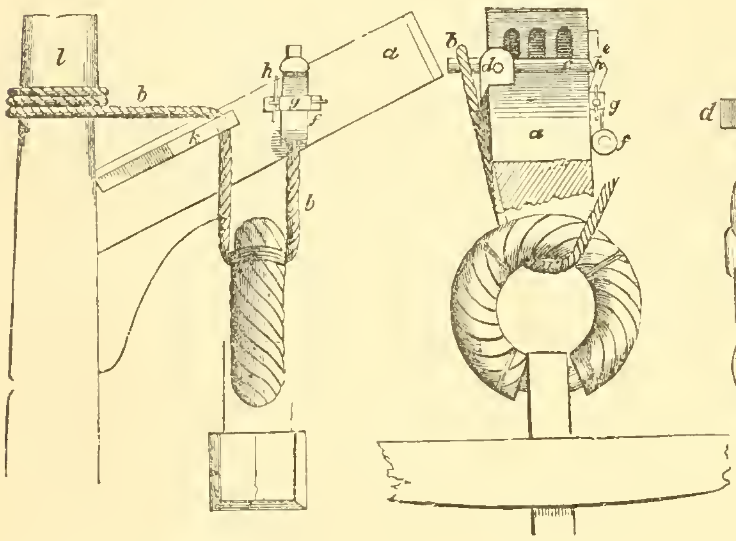


The arrangements in each of these inventions being the same, whether applied to cat-head stoppers or shank-painters, we shall therefore show one invention as applied to cat-head stoppers, and the other to shank-painters. Figs. 198 and 199 show Capt. Burton's method of letting go a cat-head stopper. $a$ is the cat-head; $b\ c$ a bolt, turning upon a pivot $d$; the end $c$ forms an oblique plane,

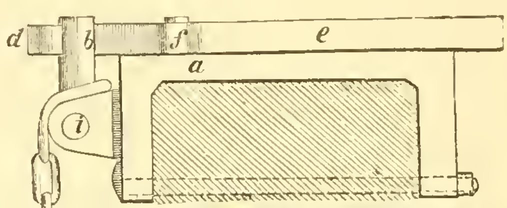
and is held down by the clamp *e* turning upon a pivot *f*, the clamp being secured by a hasp *g* and pin *h*. The standing end of the stopper, having an eye formed in it, passes over the end *b* of the bolt *b c*; the other end of the stopper passes through the ring of the anchor and over the thumb-cleat *k*, and is made fast round the timber-head *l*. When it is required to let go the anchor, a handspike is inserted between the thumb-cleat *k*, so as to nip the clamp *e*, and the hasp *g* is cast off; then, upon withdrawing the handspike, the bolt, being no longer held by the clamp *e*, turns upon its pivot *d* by the weight of the anchor on the stopper, and the eye of the stopper slips off the end of the bolt.

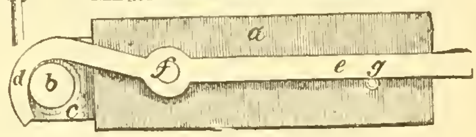
Figs. 200 and 200 A represent Mr. Spence's invention for letting go a shank-painter. Fig. 200 is an elevation, and Fig. 200 A the plan. *a* is a cast-iron carriage, bolted through the ship's side, and supporting the hook *d* by a pin or pivot at *b*; *d e* a lever turning upon a centre *f*, the end *d* being formed into a hook, which clasps the upper end of the bolt *b*, the lever being retained in the position shown in the plan by a pin *g*; *h* is part of a chain forming the standing part of the shank-painter, and supported by the bolt *b*. To the other end of the chain is spliced the running part of the shank-painter, which passes round the shank of the anchor, and is made fast to a timber-head. When it is required to let go the shank-painter, an iron bar is inserted into the end *e* of the lever

198. 199.



200.





200 A.

*d e*, which is made hollow for the purpose, and, the pin *g* being withdrawn, the lever is turned round its centre until the bolt is released from the hook *d*, when it falls, and the chain-end of the shank-painter slips off.

See also BRIDGE, and LIGHTHOUSES; for those used in other structures, see DOCKS, and PILES AND SCREW MOORINGS.

*Works, etc., relating to Anchors.*—Cotsell (G.), "Treatise on Ships' Anchors," 1856; "Parliamentary Reports on Anchors, 1860–1864;" "Rapports de la Commission du Ministère de la Marine sur l'Exposition de 1867," Paris, 1868; Lace's "Seamanship," 5th edition, 1873.

ANEMOMETER. An instrument for measuring the force of the wind. Attention was first given to this subject by Dr. Croune in 1667, and instruments were contrived by him and by Wolfius and others in the last century. These have all given place to recent inventions of more perfect construction. The first attempts were to measure the force of the wind by its pressure upon a vertical plane, kept in position by a spring or by a weight suspended by a cord wound around a conical spiral axis, which weight the wind would raise more or less according to the degree of pressure on the vertical plane. A bag of air opening into a glass tube which was shaped like the letter U, and contained a fluid which by compression of the bag was forced down one leg and up the other, was another contrivance for the same purpose. Another form of it was to dispense with the bag and turn one extremity of the tube against the wind, expanding it to a funnel shape, so that the wind might blow directly into it and press upon the surface of the fluid. The tube was drawn out to a small diameter in the curve at the bottom, so as to check the sudden fluctuations caused by irregular blasts of wind. By means of this simple instrument, Dr. Lind, who invented it, ascertained the force of the wind at different velocities by the height of the column of water raised by it. A gentle breeze, moving at the rate of nearly 4 miles an hour, raises a column of water one-fortieth of an inch, which is equivalent to a pressure of $2\frac{1}{5}$ ounces upon a square foot. A high wind moving $32\frac{1}{2}$ miles per hour raises the column 1 inch, with a pressure of nearly $5\frac{1}{4}$ lbs. on the square foot. A column of 3 inches indicates a pressure of $15\frac{1}{2}$ lbs., and a velocity exceeding $56\frac{1}{4}$ miles an hour. At 9 inches the wind is a violent hurricane moving $97\frac{1}{2}$ miles an hour, and exerting a pressure on the square foot of $46\frac{7}{8}$ lbs. The atmospheric pressure being a little over 2,000 lbs. on the square foot, or equal to a column of water 33 feet high, the greatest force exerted by the wind is feeble in comparison with this.

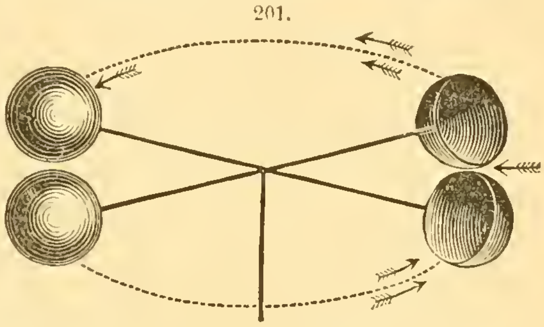
A more complicated apparatus was invented by Dr. Whewell, and another by Mr. Osler, both of which have been used in England at the meteorological observatories and government institutions. Both are self-registering, and determine the force of the wind by the number of revolutions of a

windmill fly, the axis of which by perpetual screws and toothed wheels is connected with the registering pencil. In Whewell's instrument the windmill with its wheels and vane is on a horizontal plate, which revolves on the top of a vertical cylinder. The pencil is attached to a little block of wood or nut, through which passes a screw from the horizontal plate above to a circular rim below the cylinder, all which revolves around the cylinder as the wind changes. A straight rod also goes through the pencil-block or nut, up and down which it slides as the screw turns. According as the wind blows gently or strongly, this screw turns slowly or fast, and carries the pencil down the cylinder at a proportional rate. Its point reaches the surface of the cylinder and marks upon it its position; and as the frame turns with the change of direction of the wind, the course of the wind is registered upon the face of the cylinder. For this purpose it is divided by vertical lines into 16 or 32 equal parts corresponding to the points of the compass. This instrument is deficient in not recording the time during which each wind blows, nor the times of its changes, nor its force at any particular moment. It merely gives the order of the changes of the wind, and the entire quantity that blows from each point. This is known by the vertical length of the pencil-mark in each division of the cylinders corresponding to the courses. It is defective also by the friction of its machinery.

Osler's instrument, constructed on similar principles, is more complicated than Whewell's. Its register is divided by lines into spaces, which represent the 24 hours of the day, and in these spaces pencils inscribe lines, one of which indicates the direction, another the pressure of the wind, and a third, connected with a rain-gauge, the quantity of rain which has fallen at every hour. The register moves along by clockwork under the pencils, and at the meteorological observatory at Greenwich a new one is employed every day. In the Royal Exchange in London one of these instruments is in use with a register made to last a week. By the lines inscribed on the register the integral or quantity of the wind can be calculated that has blown to each point of the compass during the periods of the observations; and thence the resultant, or average effect of all the winds.

The instrument now in use in the United States office for weather reports is Robinson's anemometer, Fig. 201, which consists of four horizontal arms radiating from a central point, at which is a vertical axis of revolution. A hollow hemispherical cup is attached to each arm in such manner that, when the wind is pressing upon the concave side of a cup on one arm, the cup on the opposite arm presents its convex side toward the wind. The wind exerts more pressure on the concave side than on the convex, and hence causes the arms to revolve. The rate of revolution per minute gives the velocity of the wind. Each instrument has to be tested by placing it upon a moving body on a calm day. In this way it is easily found what the number of revolutions is which the instrument will give for any velocity; it is then placed upon a high building, and its axis attached to a recording apparatus similar to that described above.

201.



Biram's anemometer is an instrument for measuring and registering the quantities of air which circulate through the passages of mines. It was invented in consequence of the recommendation of a committee appointed by the British House of Commons, that the use of such an instrument should be adopted as a precaution against the explosions in coal-mines. It is a disk of a foot diameter, made to revolve when placed in a current of air, and furnished with registering wheels like those upon a gas-meter. Any want of attention on the part of those having charge of supplying the required current of fresh air is thus readily detected.

An extended treatise on this subject will be found under the same heading in Spon's "Dictionary of Engineering."

ANIMAL STRENGTH. Of all the first movers of machinery, the force derived from the strength of man or other animals was first used, and at present, in a multitude of cases, is still the most convenient. As horses were formerly employed for the same purposes that water-wheels, windmills, and steam-engines now are, it has become usual to calculate the effect of these machines as equivalent to so many horses; and animal strength becomes thus a sort of measure of mechanical force.

When an animal is at rest, and exerts its strength against any obstacle, then the force of the animal is greatest; or the animal, when standing still, will support the greatest load. If the animal begins to move, then it cannot support so great a load, because a part of its strength must be employed to effect the motion; and the greater the speed with which the animal moves, the less will be the force exerted on the obstacle, or the less will be the load which it is able to carry, for the greater will be the portion of its strength directed to the movement of its own body; and there will be a speed with which the animal can move and carry no load, but where the whole of his strength is employed in keeping up its velocity.

It is clear that, in the first and last of these cases, the useful effect of the animal is nothing, in a mechanical point of view. There must, however, be a certain relation between the load and speed of the animal, in which the useful effect is a maximum. It has been found that the mechanical effect of any animal at work during a given time is greatest when the animal moves with one-third of the greatest velocity with which it can move unloaded, and the load which it bears is four-ninths of that which it can only move.

*Man and Animal Power compared.*—The following table, from Haswell's "Engineers' and Mechanics' Pocket-Book," shows the amount of labor produced by animal power under different circumstances:

| MANNER OF APPLICATION. | Power. | Velocity per Second. | Weight Raised, Foot per Minute. | Horse-Power for Given Period. |
|---|---|---|---|---|
| | Lbs. | Feet. | Lbs. | No. |
| 10 Hours per Day. | | | | |
| Man throwing earth with shovel a height of 5 feet | 6 | 1⅓ | 480 | 8.7 |
| Man wheeling a loaded barrow up an inclined plane, height one-twelfth of length | 132 | ⅝ | 4,950 | 90 |
| Man raising and pitching earth with a shovel to a horizontal distance of 13 feet | 6 | 2¼ | 810 | 14.7 |
| Man pushing and drawing alternately in a vertical direction | 13 | 2½ | 1,950 | 35.5 |
| Man transporting weight upon a barrow and returning unloaded. | 132 | 1 | 7,920 | 144 |
| Man walking upon a level | 143 | 5 | 42,900 | 780 |
| Horse drawing a four-wheeled carriage at a walk | 154 | 3 | 27,720 | 504 |
| Horse with load on back at walk | 264 | 3¾ | 59,400 | 1080 |
| Horse transporting a loaded wagon and returning unloaded at a walk | 1,540 | 2 | 184,800 | 3360 |
| Horse drawing a loaded wagon at a walk | 1,540 | 3¾ | 346,500 | 6300 |
| 8 Hours per Day. | | | | |
| Man ascending a slight elevation unloaded | 143 | ½ | 4,290 | 62 |
| Man walking and pushing or drawing in a horizontal direction. | 26 | 2 | 3,120 | 45.2 |
| Man turning a crank | 18 | 2½ | 2,790 | 39 |
| Man upon a tread-mill | 140 | ½ | 4,200 | 60.9 |
| Man rowing | 26 | 5 | 7,800 | 113 |
| Horse upon a revolving platform at a walk | 100 | 3 | 18,000 | 260.8 |
| Ox, same conditions | 132 | 2 | 15,840 | 229.5 |
| Mule, " " | 66 | 3 | 11,880 | 172.2 |
| Ass, " " | 32 | 2¾ | 5,280 | 76.5 |
| 7 Hours per Day. | | | | |
| Man walking with a load on his back | 88 | 2½ | 13,200 | 167.9 |
| 6 Hours per Day. | | | | |
| Man transporting a weight upon his back and returning unloaded | 140 | 1¾ | 14,700 | 160.5 |
| Man transporting a weight upon his back up a slight elevation, and returning unloaded | 140 | .2 | 1,680 | 19 |
| Man raising a weight by the hands | 44 | ½ | 1,320 | 14.4 |
| 4½ Hours per Day. | | | | |
| Horse upon a revolving platform at a trot | 66 | 6¾ | 26,730 | 218.7 |
| Horse drawing an unloaded four-wheeled carriage at a trot | 97 | 7¼ | 43,195 | 353.5 |
| Horse drawing a loaded four-wheeled carriage at a trot | 770 | 9¼ | 334,950 | 2741 |

*Human Strength.*—The mean effect of the power of a man unaided by a machine working to the best practicable advantage, is the raising of 70 lbs. 1 foot high in a second, or 10 hours per day. The maximum power of a strong man exerted for 2½ minutes equals 18,000 lbs. raised 1 foot in a minute. A man can travel without a load on level ground during 8½ hours per day, at the rate of 3.7 miles per hour, or 31½ miles per day. Trained pedestrians have, however, greatly exceeded this: 100 miles has been walked in 20 hours, 37 minutes, and 45 seconds; 1,000 miles in 1,000 consecutive hours (this by a young woman); and 520 miles in 6 days. Among other exceptional feats of strength which may be mentioned, are the swimming of the English Channel from Dover to Calais—distance, 23 miles in a straight line, but amounting in the accomplishment to 50 miles—by Matthew Webb, in 21 hours and 45 minutes. Agnes Beckwith, a young girl, swam 5 miles in 1 hour and 9 minutes. 13 feet 7 inches has been leaped at a standing jump. 1½ miles has been skated in 3 minutes and 6 seconds. A man has lifted 3,300 lbs. in harness, and 1,230 lbs. by the hands alone. A dumb-bell weighing 201 lbs. has been raised with one hand. One-quarter of a mile has been run in 48½ seconds. Cases of this kind indicate exceptional powers of endurance, and usually abnormal development of certain muscles. Such extreme stress on the physical powers is apt to be injurious. Dr. B. F. Richardson, in discussing the subject, says that physical overculture produces aneurism of the aorta, wearing out of the heart, and also an undue muscular development of that organ; and he further asserts that "there is not a professional athlete in England of the age of 35, who has been 10 years at his calling, who is not disabled."

An investigation has been made (1877) by Dr. Burcq, of Paris, in the *École de la Faisanderie*, a gymnasium where are drilled the soldiers who are destined to be the gymnastic instructors of the French army. No better set of men could be selected for examination, for the reason that each individual is virtually intended hereafter to serve as a model for others, and therefore his physical culture is brought to the best possible state. Dr. Burcq continued his investigations with the utmost care and minuteness for six months, during which period the progress of over a thousand men was closely watched and criticised. As a general result, he states that gymnastic exercises—1. Increase the muscular forces up to 25 and even up to 38 per cent., at the same time tending to equilibrate them in the two halves of the body; 2. Increase the pulmonary capacity at least one-sixth; 3. Increase the weight of men up to 15 per cent., while, on the other hand, diminishing the volume. This augmentation exclusively benefits the muscular system, as is demonstrated by its elevated dynamometric value. And Dr. Burcq further observes that, during the first half of the six months' course at the school, the increase of force was most markedly noted.

To Dr. Burcq's studies upon this body of trained gymnasts may be added those of M. Eugène Paz, who for a long period has been observing the results which methodical physical exercise produces in certain invalids, and in a large number of people of various callings, notably artists, literary and business men, and others, whose muscles are normally less voluminous than those of the picked soldiers at the *Faisanderie* School. By means of a variety of ingenious mechanical apparatus, and by a course of investigation wholly different from that of Dr. Burcq, M. Paz reaches precisely the same results. He notes especially the increase in weight and decrease of volume of the body, above referred to, and also the augmentation of pulmonary capacity. Three operatic singers, who were rigorously trained for a year, attained a maximum lung-power corresponding exactly to an increase of one-sixth. It follows, therefore, that Dr. Burcq's results may be considered in the light of a general law.

F. E. Nipher has determined, after a series of investigations upon variation of muscular strength, that the coefficient of muscular power per square centimetre of section of muscle is a quality which varies greatly with different muscles, and with the same muscle at different times; or, the work which a muscle can perform depends not only upon its size, but also upon its quality. Muscles which are seldom called into action have not the same contracting power as those which are daily used.

*Brute Strength.*—The following table shows the amount of labor a horse of average strength is capable of performing at different velocities on canals, railroads, and turnpikes:

| VELOCITY PER HOUR. | DURATION OF WORK. | USEFUL EFFECT FOR 1 DAY, DRAWN 1 MILE. | | |
|---|---|---|---|---|
| | | On a Canal. | On a Railroad. | On a Turnpike. |
| Miles. | Hours. | Tons. | Tons. | Tons. |
| $2\frac{1}{2}$ | 11.5 | 520 | 115 | 14 |
| 3 | 8 | 243 | 92 | 12 |
| 4 | 4.5 | 102 | 72 | 9 |
| 5 | 2.9 | 52 | 57 | 7.2 |
| 6 | 2 | 30 | 48 | 6 |
| 7 | 1.5 | 19 | 41 | 5.1 |
| 8 | 1.125 | 12.8 | 36 | 4.5 |
| 10 | .75 | 6.6 | 28.8 | 3.6 |

The actual labor performed by horses may be greater, but it is apt to injure them. The ordinary work of a horse may be stated at 22,500 lbs., raised 1 foot in a minute for 8 hours per day. See Haswell's "Engineers and Mechanics' Pocket-Book," 32d edition, 1876. For relative cost of horse-labor on street-railroads as compared with that of road-locomotives, see LOCOMOTIVE.

ANNEALING. The gradual cooling of metal or glass after the same have been highly heated, in order to render the object less brittle. See TEMPERING, etc., and GLASS.

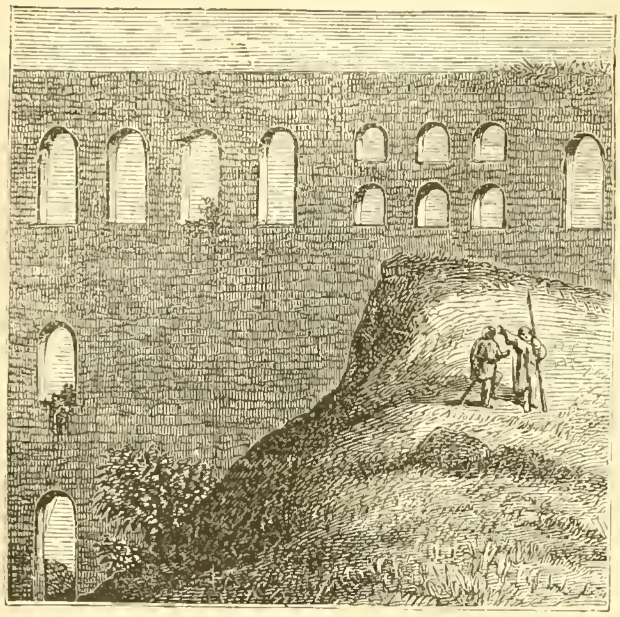
ANTI-FRICTION COMPOUNDS. See FRICTION AND LUBRICANTS.

ANVIL. See FORGE, and CARTRIDGE.

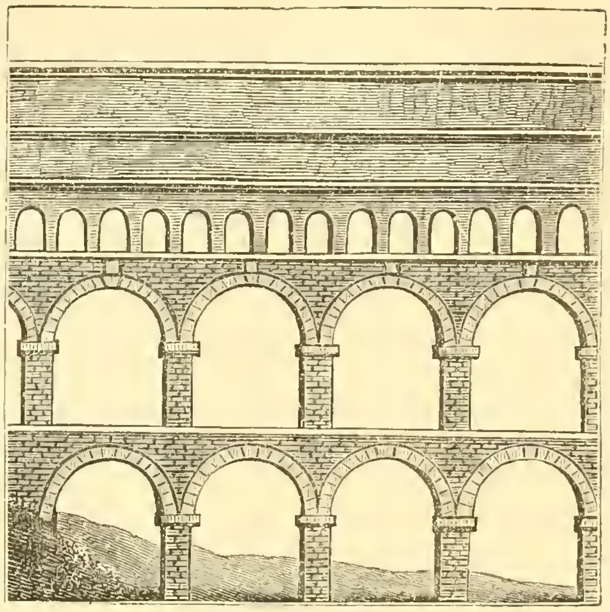
AQUEDUCT. A conduit for the conveyance of water, principally for the supply of cities for domestic purposes, or for irrigation of tracts of land, or for extending the water-way of canals over rivers and valleys. In the following article only aqueducts of the first class are treated; the others are referred to respectively under CANALS and IRRIGATION. The means employed for transporting the water are pipes and masonry conduits. As regards the relative merits of the two, where the dimensions which would be necessary for pipes are considerable, an aqueduct of masonry is preferred. The limit at which the cost of the two is equal varies very much, according to the locality, facilities of transport, and the materials and labor available. No fixed rule can therefore be given; but it may be stated (subject to correction) that, under 24 inches, pipes are almost always cheaper than masonry conduits.

The following are some of the chief ancient structures of this kind: The Aqueduct of Spoleto, constructed in 741 by Theodoric, King of the Goths, to communicate with the town of Spoleto, is situated on the summit of a mountain. It is one of the handsomest structures of the kind, and remains entire to the present day. In crossing the river *De la Morgia*, the channel-way is supported upon two tiers of Gothic arches, the lower containing 10 grand arches, and the upper 30. The length of this arcade is 800 feet, the breadth 44, and the height 420. The Aqueduct of Caserta, built in 1753 by Charles III. of Naples, is also an expensive and gigantic structure; one of its arcades consisting of three tiers of arches, 1,724 feet long and 190 feet in height. In France, that which conducts the waters of St.-Clément and Du Boulidou to Montpellier is perhaps the most beautiful. It was built under the superintendence of M. Pitot, and required 13 years for its completion. The principal arcade is 90 feet high, and consists of two tiers, the lowest containing 90 and the upper 210 arches. That of Arcueil deserves next to be noticed. It was originally built by the Emperor Julian, A. D. 360, to bring water to Paris, and supplied the palace and hot-baths, but was destroyed by the Normans. After it had been in disuse for 800 years, it was rebuilt in 1634; again repaired in 1777; and fresh sums have lately been devoted to the same purpose by the city of Paris. The arcade over the valley of Arcueil, consisting of 25 arches, is 72 feet high and 1,200 feet long. The Aqueduct of Lisbon, completed in 1738, is about three leagues in length, and in some parts of its course has been excavated through hills; but near the city it is carried over a deep valley, for a length of 2,400 feet, by several bold arches, the largest of which has a height of 250 feet and a span of 115 feet.

A portion of one of the main bridges of the Aqueduct of Antioch is represented in the annexed engraving. This bridge was 700 feet long and 200 feet high. Though solidly built, it is yet the



Aqueduct of Antioch.



Pont du Gard, Nimes.

rudest example of Roman work, and contrasts strangely with the bridge of the Aqueduct of Nimes, or Pont du Gard, across which the waters of the river Hure were led. This bridge spanned the valley of the river Gard by a triple row of arches, the first six having a span of 60 feet each; above these

High Bridge, Harlem River.

were 12 similar ones; while the upper row was composed of 36 smaller arches, arranged as in the illustration, the whole forming one of the finest examples of Roman architecture.

*Aqueduct Data.*—The following table, abridged from Fanning's "Treatise on Water-Work Engineering," gives the principal data respecting several well-known masonry conduits:

*Table showing Dimensions, etc., of Aqueducts.*

| LOCALITY. | Width. | Height. | Depth of Water. | Velocity of Flow per second. | Daily Delivery at given depth. | Total Daily Capacity. |
|---|---|---|---|---|---|---|
| | Feet. | Feet. | Feet. | Feet. | U. S. Gals. | U. S. Gals. |
| Cochituate, Boston | 5. | 6.333 | 6.333 | 1. | 16,398,980 | 16,500,000 |
| Croton, New York | 7.417 | 8.458 | 6.083 | 2.218 | 59,340,243 | 100,000,000 |
| Washington Aq., D. C. | 9. | 9. | 3.465 | 1.893 | 27,559,364 | 100,000,000 |
| Brooklyn, L. I. | 10. | 8.667 | 5.00 | ...... | ......... | 70,000,000 |
| Sudbury, Boston | 9. | 7.667 | 5.3 | ...... | ......... | 70,000,000 |
| Baltimore | 9. | 9. | ..... | ...... | ......... | 170,000,000 |
| Loch Katrine, Glasgow | 8. | 8. | 6.85 | 1.7126 | 60,000,000 | 60,000,000 |
| Canal Isabel II., Madrid | 7.0522 | 9.184 | ..... | ...... | ......... | 52,000,000 |
| Vienna | 5.667 | 6. | ..... | ...... | ......... | ......... |
| Vanne, Paris | 6.6 | 6.6 | 5.00 | ...... | ......... | 23,500,000 |
| Dhuis, " | 2.3 | 3.5 | ..... | ...... | ......... | 5,500,000 |
| Pont du Gard, Nimes | 4. | ..... | 3.33 | ...... | .... .... | ......... |
| Pont Pyla, Lyons | 1.833 | ..... | 1.833 | ...... | ......... | ......... |

*The Croton Aqueduct.*—The following description of the Croton Aqueduct gives many of the details of aqueduct construction. This great work was begun in 1837 and completed in 1842, at a total cost of $12,500,000. Its length from its source at Croton River to the reservoir in New York is

$40\frac{1}{2}$ miles, 33 miles of which distance it is built of stone, brick, and cement, arched above and below. It has a capacity for discharging about 100,000,000 gallons per day. The Croton River rises in Putnam County, New York. At the spot where the first dam is constructed the surface-water was about 38 feet lower than the elevation required as a head for the delivery of water into the city of New York. The effect of the dam was to set back the water about six miles, forming the reservoir, which has an area of about 400 acres, now called Croton Lake. The available capacity of this reservoir, down to the point where the water would cease to flow into the aqueduct, is estimated at 600,000,000 gallons; in addition to which, the receiving-reservoir in the city is capable of containing 150,000,000 gallons more when full, which together afford a reserve-supply of 750,000,000 gallons in seasons of extreme drought. In case of necessity, several large lakes in Putnam County may be turned into the river or aqueduct. The following table shows the various lengths and inclinations of the conduit:

| LENGTHS AND INCLINATIONS. | Distances in Miles. | Distances in Feet. | Fall in Feet. |
|---|---|---|---|
| From the dam to the meeting of the general inclination... ................. | 4.9490 | 26,130 | 2.9507 |
| From here to Harlem River the general inclination 0.021 per 100 or 1.1088 feet per mile of 5,280 feet.................................. | 27.9316 | 147,479 | 30.9700 |
| At the aqueduct-bridge of Harlem River to the general inclination 2 feet are added, the water being carried over in pipes by a siphon of 12 feet........ | 0.2750 | 1.450 | 2.3450 |
| To Manhattan Valley, the general inclination of 1.1088 feet per mile ......... | 2.0140 | 10,635 | 2.2334 |
| Across Manhattan Valley the water passes in a siphon of 109 feet head, for that reason 3 feet are added to the general inclination..................... | 0.7917 | 4,180 | 3.7783 |
| From here to the receiving-reservoir 9 inches per mile...................... | 2.1727 | 11,471 | 1.6295 |
| From the influence-gate of this reservoir to its effluence-gate............... | 0.1720 | 908 | 0.0000 |
| To the distributing-reservoir the water is carried in a siphon by pipes for the entire distance.......................................... | 2.1760 | 11,489 | 4.0000 |
| Distributing-reservoir........................................ | 0.0800 | 420 | 0.0000 |
| | 40.5620 | ............ | 47.9069 |
| These 47.9069 feet form the fall at the bottom of the aqueduct; at the head this bottom is 11.4633 feet below the surface of the lake, but only 8.2000 feet at the discharge in the receiving-reservoir, which gives 8.2633 feet difference, added to the fall at bottom; this makes the entire fall, or the accurate difference between the surface of the Croton Lake and that of the distributing-reservoir... ............................ | ........................ | | 3.2633 |
| | ........................ | | 51.1702 |

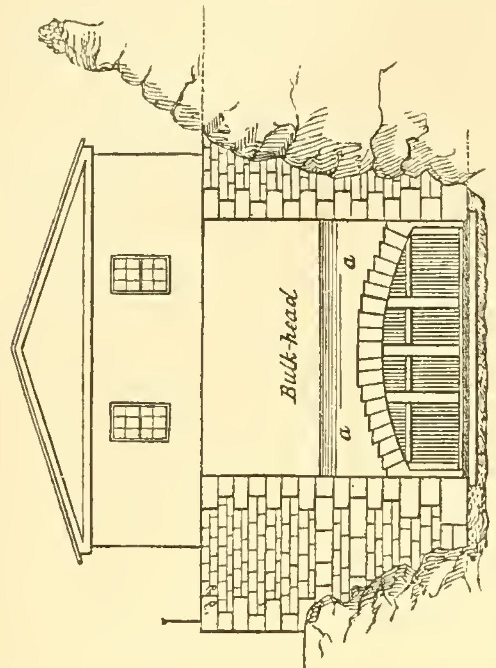
*Construction of Aqueduct-Canal.*—Where the masonry of the aqueduct is cut in level ground or side-hills, a course of concrete 3 inches high is laid under the whole extent of masonry, under the extrados of the inverted arch, as high as the shape of the extrados required. Where water-veins were met, and in loose ground, or where the depressed ground made foundation-walls necessary, the concrete bedding was put 12 inches high, as broad as the clear width of the aqueduct, but under the side-walls only 6 inches. In both cases each of the side-walls was carried up 13 inches perpendicularly, by which the spring-line of the inverted arch was reached; after this the inverted arch was turned one-half a brick 4 inches thick, the stone part of the side-walls carried up 4 feet high, and on both sides plastered three-eighths of an inch thick with hydraulic mortar. When these walls had set, the inner facing, one-half a brick 4 inches thick, was carried up; at last the roofing-arch, 1 brick 8 inches thick; then the spandril-backing, over which and the upper part of the extrados plaster of three-eighths of an inch thickness was laid on and smoothed off with the trowel. Where suitable stone was to be had near, the side-walls could be carried up; also the roofing-arch, which in this case was turned 12 inches thick; this, however, has been carried into execution in but few instances. The courses of masonry were leveled off every 12 inches, and no stone put in which reached through the wall or raised over the course of 12 inches. Granite, or gneiss of the most sound quality, was used.

The hydraulic mortar at tunnels, and deep cuts in earth and rock, had the proportions of 1 part cement to 3 sand; upon foundation-walls, however, 1 part cement to $2\frac{1}{2}$ sand in volume; the same proportion for concrete. The sand for concrete, containing coarse and fine grains, was first mixed with water, then there was added to it from 2 to $2\frac{1}{2}$ broken stone of the size of $1\frac{1}{4}$ inch, or the same amount of coarse gravel, and worked till the mass became uniform, and the broken stone completely covered and bedded in the mortar. Immediately after this preparation the concrete was laid and settled with a stamper, till the surface had the appearance of an even floor. The courses were laid not over 6 inches thick. For brick masonry the proportion of cement to sand was 1 to 2. The mortar for vertical joints was put to the brick before laid, the brick forced into its bed in such a manner that from horizontal and vertical joints the mortar is readily forced out like sausages; the superfluous mortar was then taken off and the joints smoothed immediately. Only bricks of superior quality were admitted—No. 1 for the inverted arch and the facing, No. 2 for the roofing-arch.

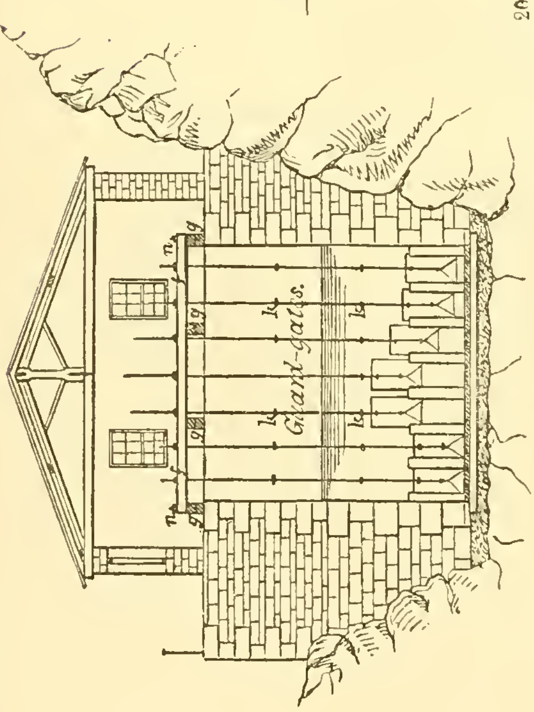
*Culverts.*—In order to carry off rivers, creeks, and field-waters, underneath the aqueduct, culverts were constructed at a suitable depth. Their fall or inclination was 1 in 20; and where the upper end happened to be below the surface of the ground, generally the case at side-hills, a well was constructed, Figs. 207 and 210. The culvert, Figs. 210, 211, and 212, is one of the smallest dimensions, with bottom and roof of stone slabs; that of Figs. 207, 208, and 209, is a large one; bottom and roofing are of smooth, well-wrought stone; the side-walls only faced with it, while the backing of this face-work is of rough masonry. In the body of the foundation-wall of the aqueduct an arch of dry stone, without mortar, was rolled over the extrados of culvert, Fig. 209; after this the foundation was carried farther up. The fall-well at the arched culverts is round in plan, Fig. 208.

*The Gateway.*—From the effluence of the lake a tunnel is cut through solid rock 180 feet in length. It has no facing of masonry, and in dimensions is kept somewhat larger than the general aqueduct, Fig. 203. The ground is uncommonly favorable for the construction of the gateway,

202.




204.

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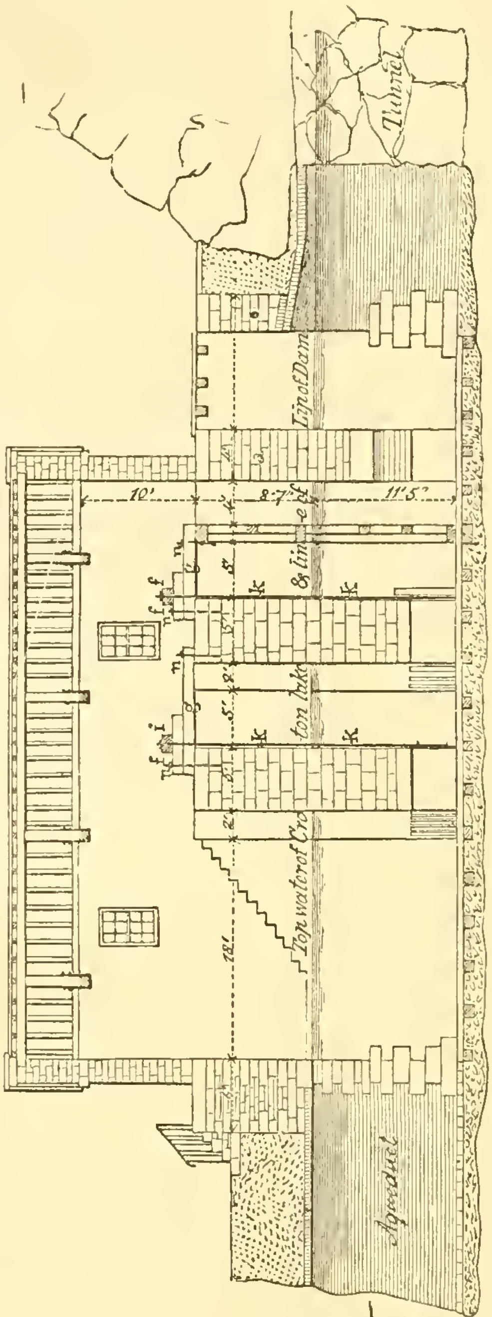


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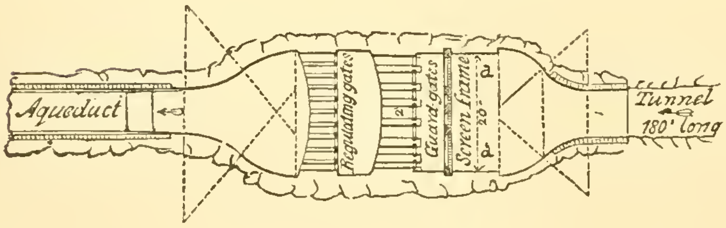
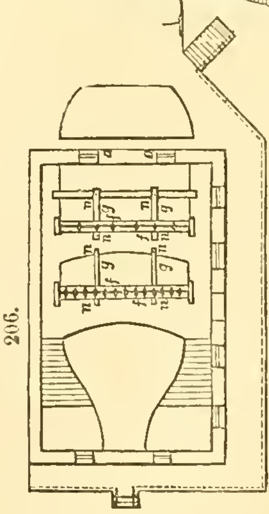



206.



SCALE.—1 inch = 40 feet.

offering rock-foundations throughout. As shown in Fig. 205, the channel of the aqueduct is widened, and the water runs through an arch in the bulkhead *a a*, then passes the screen-frame, a set of guard-gates, and a set of regulating-gates. The screen, formed of oak slabs 6 inches by 1, allowed a quantity of fish to pass through the 1-inch spaces into the aqueduct. In order to prevent this, a fine brass netting was put over the screen, through which only very small fish could pass; to prevent which, other artificial preparations will be required. Below the wall with the regulating-gates, the width of the water-way is reduced to the general width of the aqueduct by an ogee curve, in order to let the water into the proper aqueduct without any loss of fall.

The guard-gates with their frames are of cast-iron. The regulating-gates with their frames are of gun-metal, in order to obtain a superior tightness. The caps *f f*, Fig. 203, are secured upon the saddles *g g* by bolts. In turning to the left the female screw, whereby the shover is raised, the saddles with the caps press upon the base and are kept closer and closer upon their bed; in screwing right, however, they press upward. To prevent their loosening and lifting, the screw-bolts *n n n* are put in; they reach down through two courses of stone, and there they are bent; some of them are secured to the caps of the screen-frame. In shutting the gates by turning to the right, the bolts *n n* secure the caps *f f* to their places and prevent their lifting. The masonry in all parts of the gateway is of rough gneiss in hydraulic mortar, faced with well-hammered stone; the partitions between the gates are of cut stone. To keep the gates and utensils secure, a stone house is erected over the gateway.

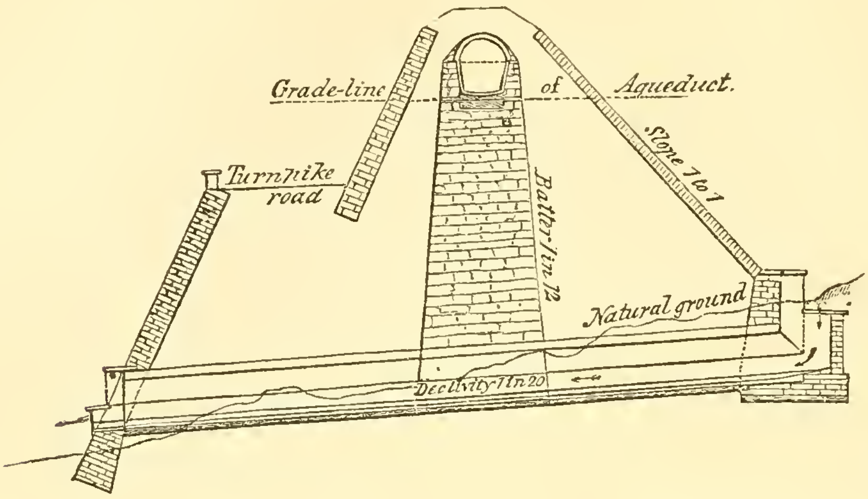
The line of the aqueduct follows the left bank of the Croton River for 5 miles, passes through several tunnels cut through the rock, and crosses the valley of the Sing Sing Kill. Across the stream an arch of 88 feet was required. The abutment-walls of this bridge are 20 feet thick, on solid rock-foundation. The arch is constructed over a half-oval, 33 feet in height, 4 feet thick at the spring-line and 3 feet at the keystone; the granite and gneiss for it was cut with much accuracy, not allowing the joints to be over three-sixteenths of an inch thick. The spandrils were carried up solid, sloping upward, thence with hance-walls and alternating openings, till 3 inches over the highest point of extrados: these openings were arched over with half a brick. Across those openings the hance-walls were connected together by bond-stone. On the top of the small brick arches a rubble masonry of 6 inches in height was laid, and the whole leveled off; on this the concrete course of 9 inches height to the extrados of the inverted arch of aqueduct. As far as the clear width of the bridge-arch and its abutments extended, the construction of the aqueduct was so altered, that the side-walls were carried up 5 feet high instead of 4, as in ordinary aqueduct, and the arch was turned over a segment of 7 feet 7 inches long, 2 feet 8½ inches high. Bottom and side-walls were provided with a lining of cast-iron worked in with the masonry, whereby the aqueduct was rendered absolutely water-tight above these constructions. The same iron lining was applied also at the before-mentioned street-bridge. Between the attic-wall and the side-wall of the aqueduct spaces were left, covered over, above the attic-wall, carried up in connection with the side-walls of the aqueduct, and covered with a coping-stone, the whole then filled over with earth. The spaces serve not only for protection against frost from without, but also for carrying off the water falling from the sky on the back-filling down into the hollows. Upon the extrados of the bridge-arch the drainage-water runs over the tangental surface of the spandril-backing into the dry foundation-wall. The surface over which the water drains is well plastered with hydraulic mortar. The exterior masonry of both the bridges is of well-hammered stone. Throughout the structure hydraulic mortar was used. For the distance of aqueduct between the bridges and back of them to the side-hills the rock-bottom was prepared with steps, and a foundation-wall of dry stone-masonry carried up. The exterior faces of some thickness into the wall were laid in hydraulic mortar, and the joints pointed with the trowel.

From this point it is not necessary to trace the line in detail, and we therefore proceed at once to the termination of the aqueduct on the continent. The valley of the Harlem River, at a point 33 miles distant from the Croton Dam, slopes down gradually until it reaches the water's edge. The tide-water has here a width of 620 feet. The bank of the island, being of solid gneiss-rock, rises with a slope of 35° to the height of the top of the aqueduct. The slope of this rock below water, as far as it could be examined, is steeper, and disappears under a deposit of mud mixed with sand and bowlders. It is supposed this rock has connection with that of the opposite shore. In the basin formed by its depression below the strait is deposited a mass of white marble, upon which the gneiss and alluvium of sand, mixed with pieces of rock and bowlders, are found, upon which mud consisting chiefly of vegetable matter is deposited.

The bridge on which the aqueduct is carried over the strait has 15 arches, 8 of which are 80 feet in width by 100 feet in height above flood-tide, placed in the water, and upon both the shores 7 arches of 50 feet span each; two abutments were founded on the gneiss-rock, three upon the marble, and seven on piles. With this arrangement the conduit-water is carried across to the island in a siphon of 12 feet depression.

In order to take the water out of the aqueduct and let it into the pipes, and, after passing over the bridge, redischarge the same into the aqueduct, 2 gate-chambers, *a* and *b*, Fig. 217, are placed. Fig. 230 shows the ground-plan, Fig. 229 the longitudinal section, and Fig. 228 the cross-section of the influence gate-chamber (entrance into the siphon); *C C* is a basin, the bottom of which is level with the deepest line of the intrados of the inverted arch; *d d* are the gateways; *e e* the two pipes; the influx of the water can be regulated by the two cast-iron double gates *K K*; *f g h* is a waste-wear, whereby the waste-water, or the whole content of the aqueduct, may be let off; *f* is the gateway, *g* the waste-wear well, *h* the sewer. The construction of the latter for the first 30 feet in length is shown by Fig. 232; following the slope downward, it is funneled into the shape and construction of Fig. 231, which leads to Harlem River. Fig. 228 is the section of gateway for the waste-wear; Fig. 229 the elevation of front with the gates *l l*. All the gates are of shape and construction as shown at Fig. 202. The rod-caps of waste-wear are connected by the bolts *m n*, Fig. 228, with the consols *n*; but the rod-caps of the gateways by the bolts *m n*, which are kept down and secured in the pier below by the cross-

207.

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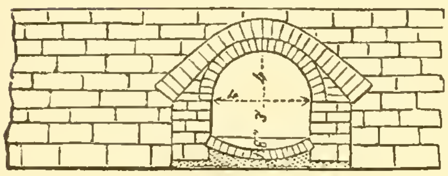

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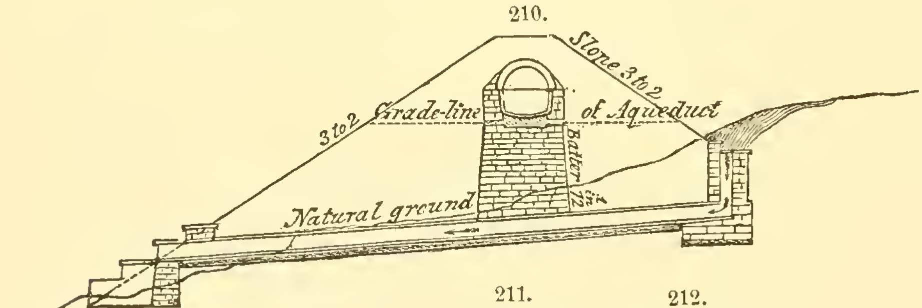


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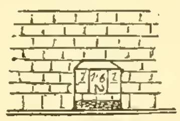

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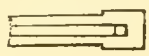

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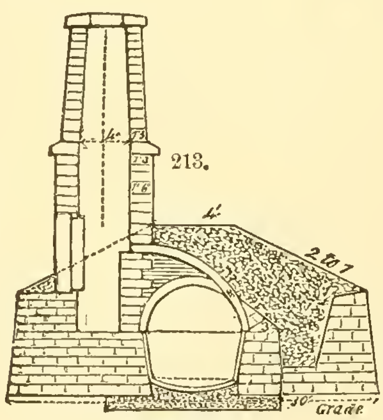


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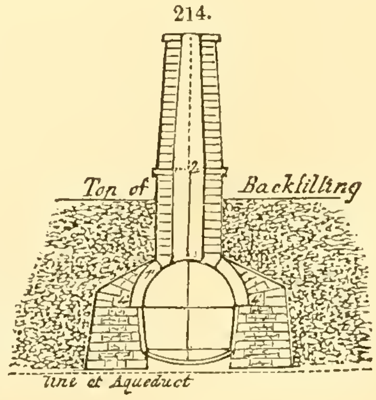


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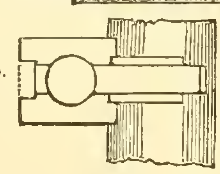

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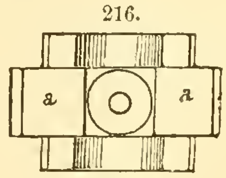
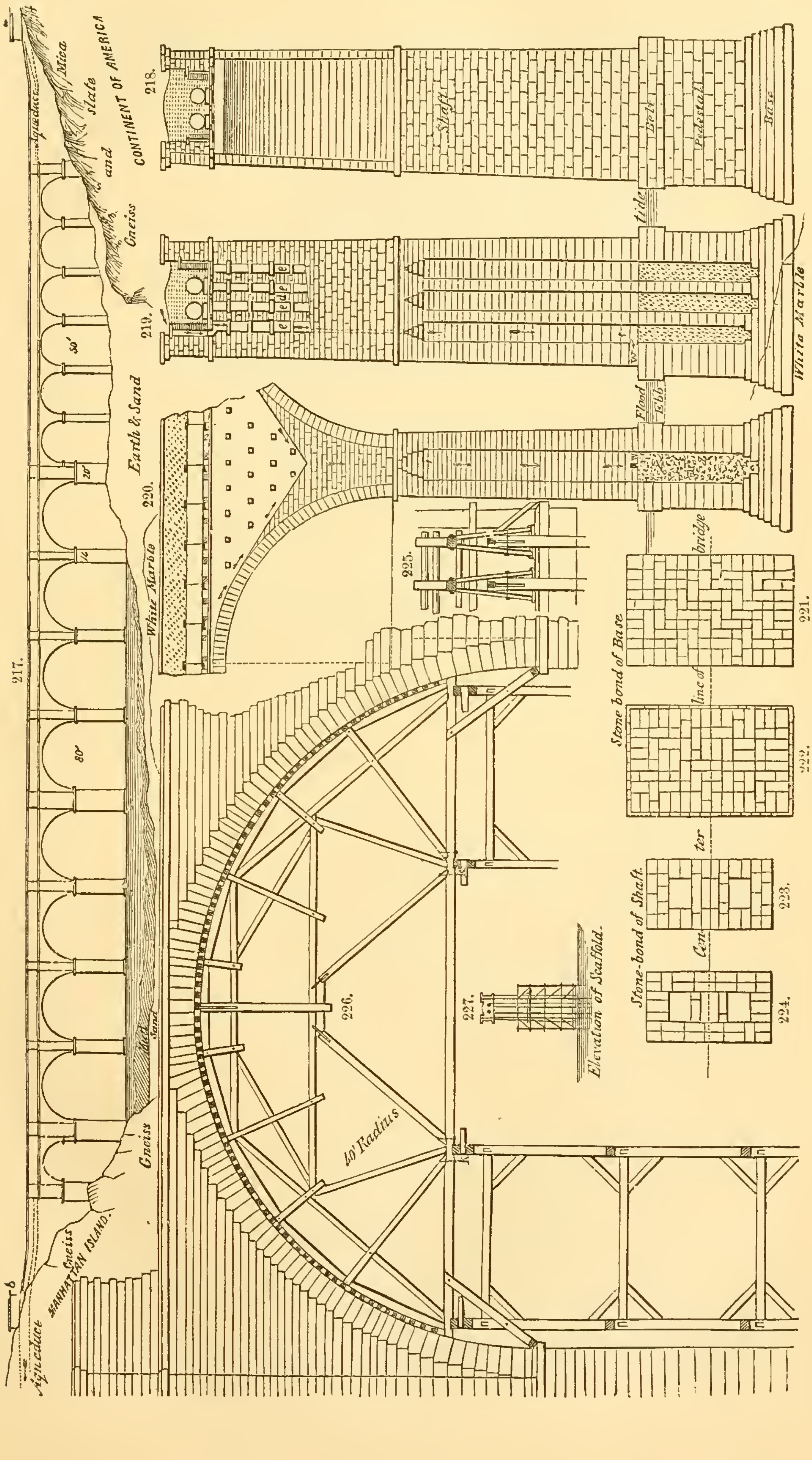
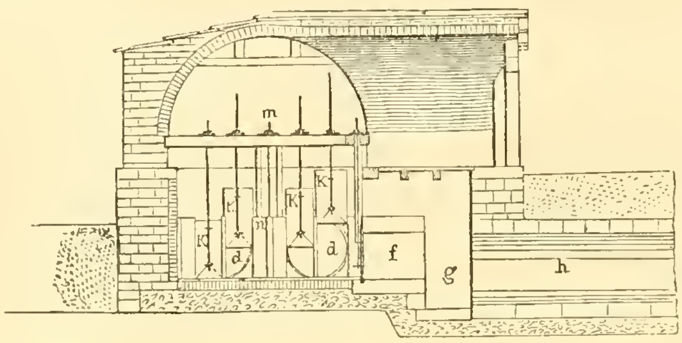



SCALE.—1 inch = 40 feet.

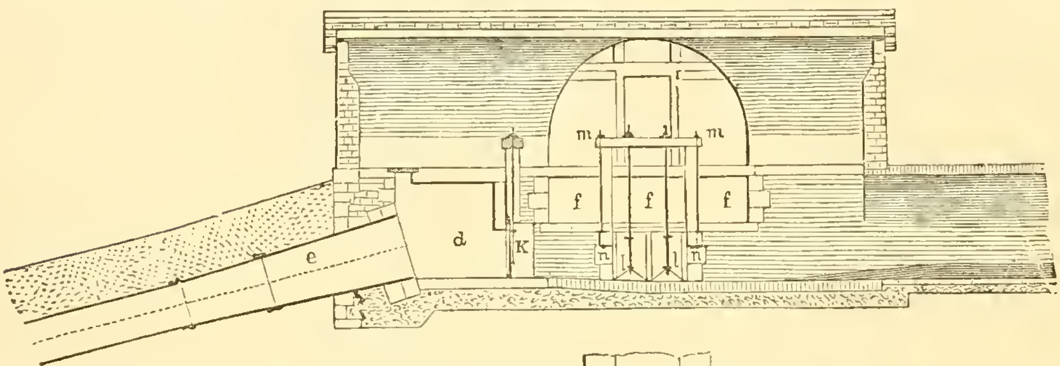

217.
Aqueduct
Mica slate and Gneiss
CONTINENT OF AMERICA
Earth & Sand
White Marble
Sand
Gneiss
MANHATTAN ISLAND.
80'
50'
20'
218.
Shaft
Belt
Pedestal
Base
219.
tide
Flood
Ebb
White Marble
220.
221.
222.
Stone bond of Base
line of center of bridge
223.
224.
Stone-bond of Shaft.
225.
226.
40' Radius
227.
Elevation of Scaffold.

piece *n*. Over the entire structure a stone building is erected, arched with bricks, and covered with 3-inch graywacke slabs. The effluent-gate *b*, Fig. 217, at the island-extremity of the bridge, is of the same arrangement in reversed order, but without waste-wear; it receives the water from the pipes of the siphon, and discharges it again into the aqueduct. From the bridge the aqueduct passes through Manhattan Valley and through Manhattan Hill tunnel, the longest of the whole line—worked 1,215 feet through rock. The receiving-reservoir, located in the middle of New York City, in Central

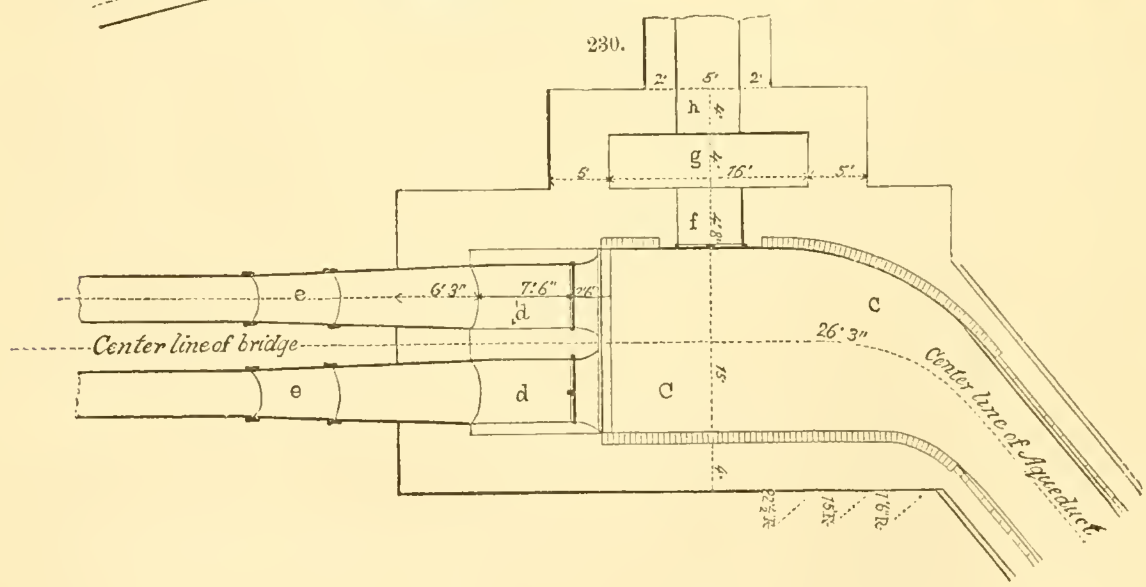
228.




229

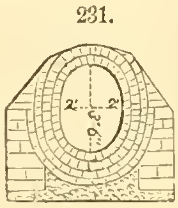


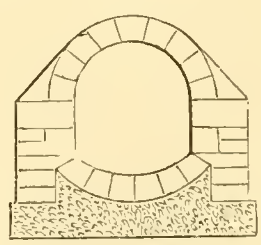

230.




232.

231.



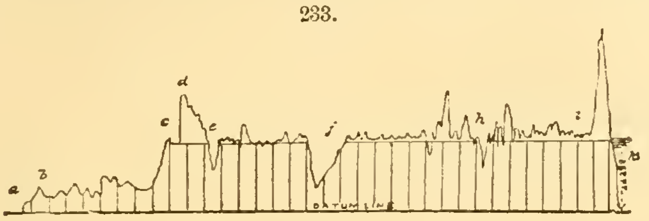


Park, has a water-surface of 31 acres. Distribution of the water throughout the city is effected through about 400 miles of cast-iron pipes. A storage-reservoir has been constructed at Boyd's Corners, on the west branch of the Croton, 23 miles from the Croton Dam. It has a water-surface of 279 acres, and a maximum depth at the dam of 57 feet.

The Aqueduct of the Loch Katrine Water-Works, which conducts water into the city of Glasgow, is 34 miles in length, has an inclination of 1 in 6,336, and is capable of passing 50,000,000 gallons daily.

The valleys of Duchray, Endrick, and Blane, *e*, *f*, *h*, Fig. 233, aggregating 3$\frac{3}{4}$ miles in length, are crossed by cast-iron siphon-pipes 48 inches in diameter, with a mean fall of 1 in 1,000 between their extremities. In Fig. 233, *a* is the river Clyde, *b* the city of Glasgow, *c* Mugdock Reservoir, *d* Mugdock Tunnel, *e* Blane Valley, *f* Endrick Valley, *g* Duenmore Tunnel, *h* Duchray Valley, *i* Loch Katrine Tunnel, and *k* Loch Katrine. The minor ravines of the first ten miles are crossed by bridges; an example is given of one made of wrought-iron tubes, Figs. 234 and 235, 8 feet broad and 6.5 feet high

233.



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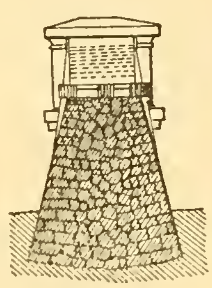

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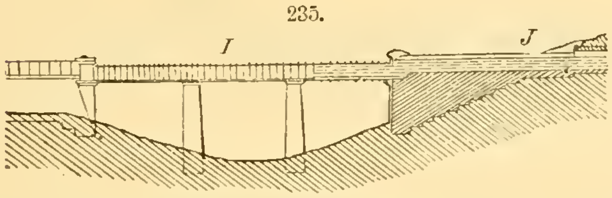



inside. A cast-iron trough *J* of the same dimensions extends over portions of the valleys where the ground is not much depressed. The tubes are supported by masonry piers 50 feet apart. The level of the tube *I* is about 3 feet lower than that of the cast-iron trough *J* at each end, in order to insure the tube being always filled with water, so as to maintain an equal temperature of the metal. Discharge-valves are placed in the tubes, so that the water can always be run off in the valley beneath. The tube also rests at the ends on an India-rubber bolster; and similar vertical bolsters are wedged against the sides at the joint with the cast-iron trough. This leaves the tube free to contract and expand longitudinally under change of temperature, without risk of leakage.

In the entire line of the aqueduct there are, in all, 25 important bridges of iron and stone, and about 80 distinct tunnels, aggregating some 13 miles. The cast-iron siphon-pipes are carried down and up the sides, and along the bottom of the three valleys. They have ordinary spigot and socket joints, and are strengthened by projecting webs cast upon them. They are protected from the effects of weather, and thus kept from injurious expansion and contraction, by a $\frac{3}{4}$-inch covering of felt enveloped in tarpaulin.

The Washington Aqueduct, which supplies the cities of Washington and Georgetown with water from the Potomac River, 11 miles distant, consists for the greater part of its length of a masonry conduit 9 feet in internal diameter. The total length of the aqueduct is 16$\frac{1}{6}$ miles, and it is capable of supplying 100,000,000 gallons per day. The most remarkable feature is the bridge over Cabin John Creek, which is stone-arched, having a span of 220 feet. The arch is an arc of a circle 134.28 feet in radius, and its rise is 57.26 feet. The channel through which the water passes consists of a conduit of circular section 9 feet diameter inside, and 9 inches thick, imbedded in the masonry. The bridge over Rock Creek may also be noted. The water is carried across this stream (which divides the cities of Washington and Georgetown) by means of two arches of cast-iron pipes of 3 feet 6 inches interior diameter, formed of sections with flanges firmly screwed to each other, and braced. Upon these is laid a bridge over which the street-cars pass, and which serves as a public avenue of communication between the two cities. The span is 200 feet, and the rise 20 feet.

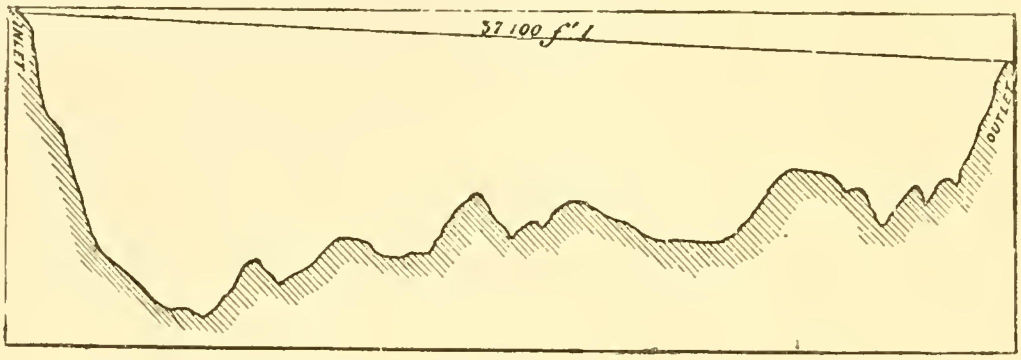
The Madrid Aqueduct.—The aqueduct which supplies Madrid, Spain, with water from the river Lozoya is 47 miles in length. The river gorge is crossed by a cut-stone dam 98 feet in height, its wings abutting upon the solid rock of the hill-sides. The transverse section of the water-way has an area of 20 square feet. The discharge is 6,600,000 cubic feet of water daily, about four-fifths of which is used for irrigating a tract of some 5,000 acres.

Paris Aqueducts.—The water-supply of Paris, France, is derived from two great spring-water aqueducts. The springs of the Dhuis, in the Department of the Aisne, are situated at a level of 128.5 metres above the sea; that of the reservoirs at Ménilmontant is 107.85 metres. The total fall of the aqueduct, which is 134 kilometres long, is therefore only 20.63 metres, and this is unequally distributed over the length. The cross-section is egg-shaped, 1.10 × 0.70, the masonry of ashlar being only 20 centimetres thick, and the whole section is coated by a layer of Portland cement 2 centimetres thick. The intrados of the arch is similarly covered down to the springing. The water-supply obtained amounts to about 5,500,000 gallons daily. The plan of the Ménilmontant reservoir is a large semicircle of 188 metres diameter, joined to a rectangle 188 metres by 42. The Vanne aqueduct, which conducts water from the springs of the Vanne, in the Department of the Yonne, is calculated to supply about 23,500,000 gallons daily. It has an average falling gradient of 0.13 per 1000. The cross-section is circular, the diameter being 2.14 metres; the masonry is 0.3 metre thick at the springing, reduced to 0.20 metre at the crown and centre of invert, and is of ashlar masonry, laid on hydraulic-lime mortar. The inner coat of cement extends 10 centimetres above the theoretical highest water-line, and the extrados of the arch is also covered with cement. The total length of the aqueduct is 137 kilometres 630 metres, of which 58.5 kilometres are in cutting, 35.5 kilometres in tunnels, 25.8 on arches, and 17.8 in inverted siphons. The length of tunnel and arching is therefore enormous. The siphons consist of two cast-iron pipes 42 inches in diameter. The reservoir at Montrouge

covers an area of about 9½ statute acres, and consists of two stories, of which the lower one is 5.5 metres high, and has a capacity of 44,000,000 gallons, while the upper story is 3.10 metres high, and has storage for 25,000,000 gallons more.

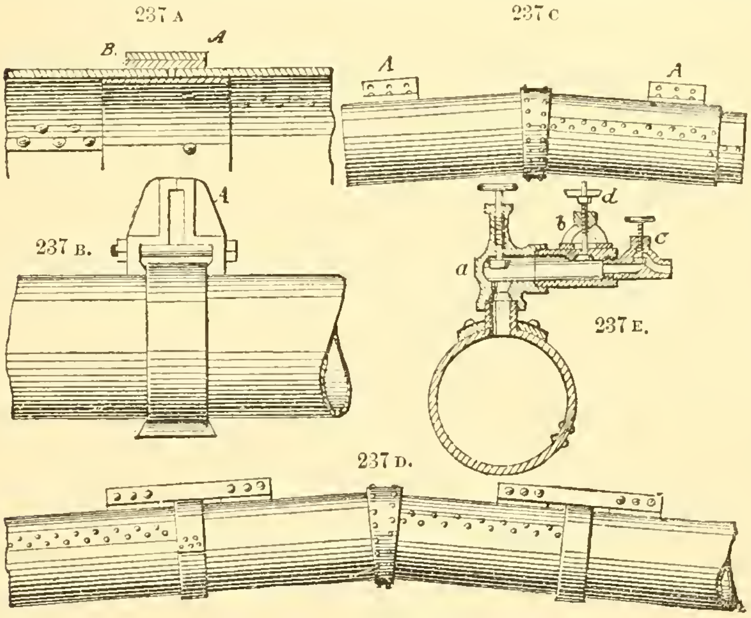
The Virginia City (Nevada) Aqueduct.—The iron pipe which carries the water-supply to Virginia City and Gold Hill, Nevada, from Marlette Lake, probably sustains the greatest natural water-pressure in the world, namely, 1,720 feet, or 750 lbs., to the square inch. The most difficult part of the undertaking begins at an elevation of 1,855 feet above the track of the Virginia and Truckee Railroad, and, following by an easterly course the crest of the spur from which it starts, crosses the valley and

236.




gradually ascends to its outlet end, making the entire length 37,100 feet. The average diameter of the pipe is 11½ inches, and its entire weight about 700 tons. The pressure gradually decreases as the ground rises to the east and west, and the iron decreases in thickness from five-sixteenths to one-sixteenth of an inch toward both inlet and outlet. The inlet had a perpendicular elevation above the outlet of 465 feet, which gives sufficient head to insure a supply of 2,350,000 gallons daily. Fig. 236 will convey an idea of the country over which this undertaking was carried out, as it shows a profile of the pipe. Fig. 237 A shows a lead joint in detail. One of these joints is made between every two lengths of pipe of 26 feet 2 inches in length each. *A* is a wrought-iron collar, always one-sixteenth of an inch thicker than the thickness of iron in the respective pipe, leaving a play of three-eighths of an inch between the inside of the collar and the outside of the pipe. *B* is the lead, which is run in and calked up tight from both sides three-eighths of an inch thick. A nipple of No. 9 iron is riveted in one end of each pipe. Fig. 237 B shows the method of tightening leaky joints. At *A* is the clasp, the application of which for forcing back the lead where it works out, on account of the longitudinal expansion and contraction of the pipes, is clearly evident. Fig. 237 C is the elbow used for making short curves in the line of the pipe around rocky bluffs, etc. At *B* are angle-irons

237 A 237 C 237 B. 237 E. 237 D.



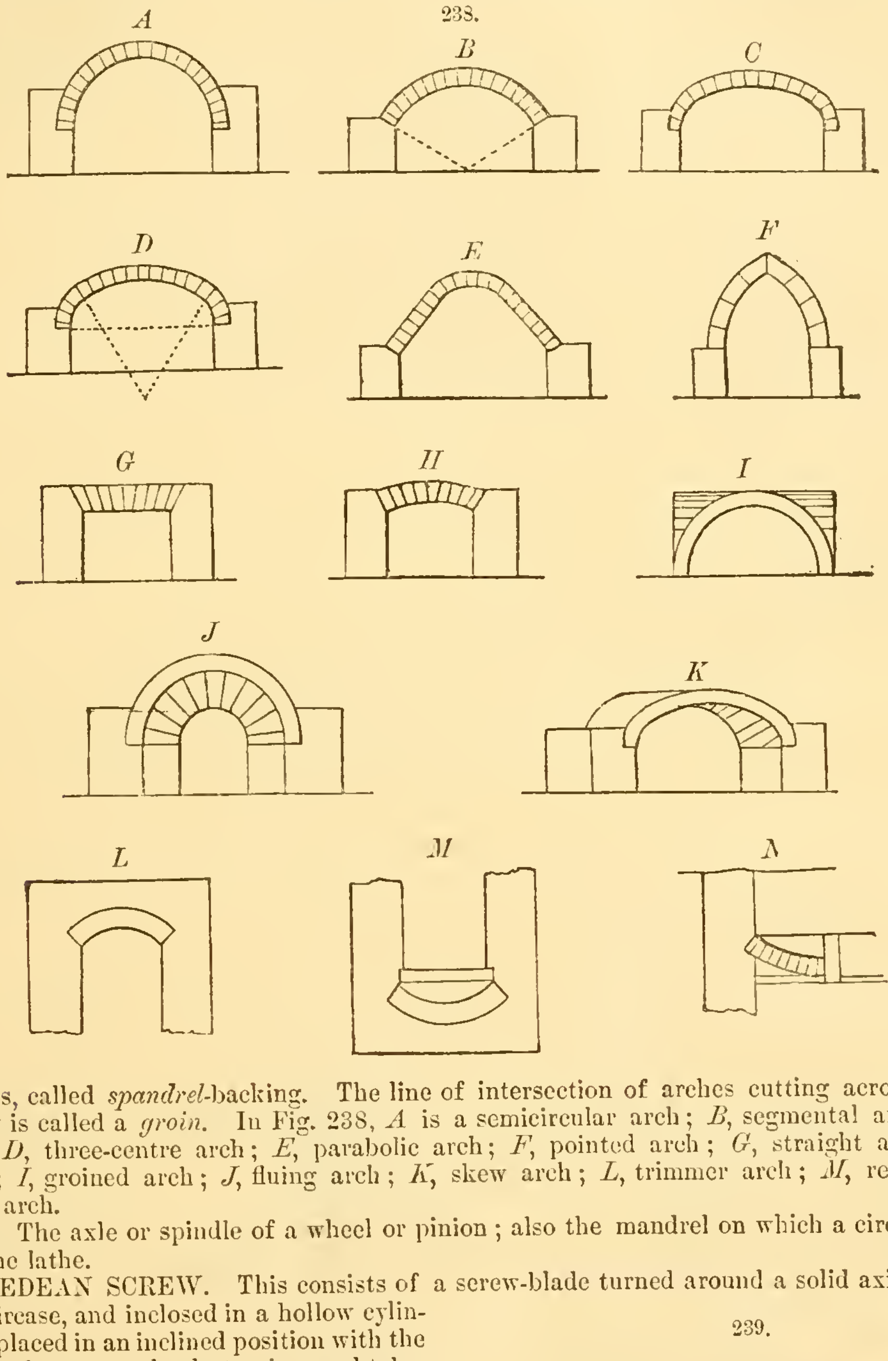

riveted on the pipe on the outside of the curves, which by means of iron straps are connected with the corresponding angle-iron on the next pipe. Fig. 237 D shows the mode of strapping together pipes and elbows; and Fig. 237 E is the self-acting air or vacuum valve used at each high point on the line of pipe. When the water is on, the valve *a* is kept wide open; the small valve *c* is shut, while the valve *b* is closed by the pressure. If any air accumulates in the pipe, on the elevation where this air-cock is placed, it is occasionally blown off by opening the cock *c*. Should a break occur in the main line at a point lower than the air-cock and within its district, the valve *b* falls down and admits the air into the main pipe, so as to prevent a vacuum. Should the valve *b* get out of order, the valve *a* is shut, and the other valve *b* taken off and repaired. After a break on the main line is repaired and the water let on again, the valve *b* being down or open, the air rushes out at *b*, its stem being weighted by the weight *d*, so as only to close when the water begins to escape. See Hydraulic Mining.

*Works for Reference.*—"On the Loch Katrine Water-Works," Gale, Proceedings Inst. M. E., 1864; "Croton Aqueduct," Tower, 1843; "Water-Works, Ancient and Modern," papers delivered before Austrian Institute of Engineers and Architects, by E. H. D'Avigdor, December, 1875, January, 1876; "Water-Supply of Cities and Towns," Humber, London, 1876; "A Treatise on Water-Supply Engineering," J. T. Fanning, New York, 1877.

ARCHES. Arches are of various shapes, as pointed, elliptical, segmental, and circular. The outer surface of the arch is called the *extrados*, or back of the arch; the inner or concave surface the *intrados*, or the soffit. The joints of all arches should be perpendicular to the surface of the soffits. The stones

are called *arch-stones*, or voussoirs. The first course on each side are termed *springers*, which rest on the imposts or abutments. In case of a segmental arch, the course beneath the springers are called *skew-backs*. The extreme width between springers is called the *span* of the arch, and the versed sine of the curve of the soffit the *rise* of the arch. The highest portion of the arch is called the *crown*, and the centre course of voussoirs the *key-course*. The side portions of arches between the springing and the crown are termed *haunches*, or flanks. All arches should be well sustained by backing on

238.

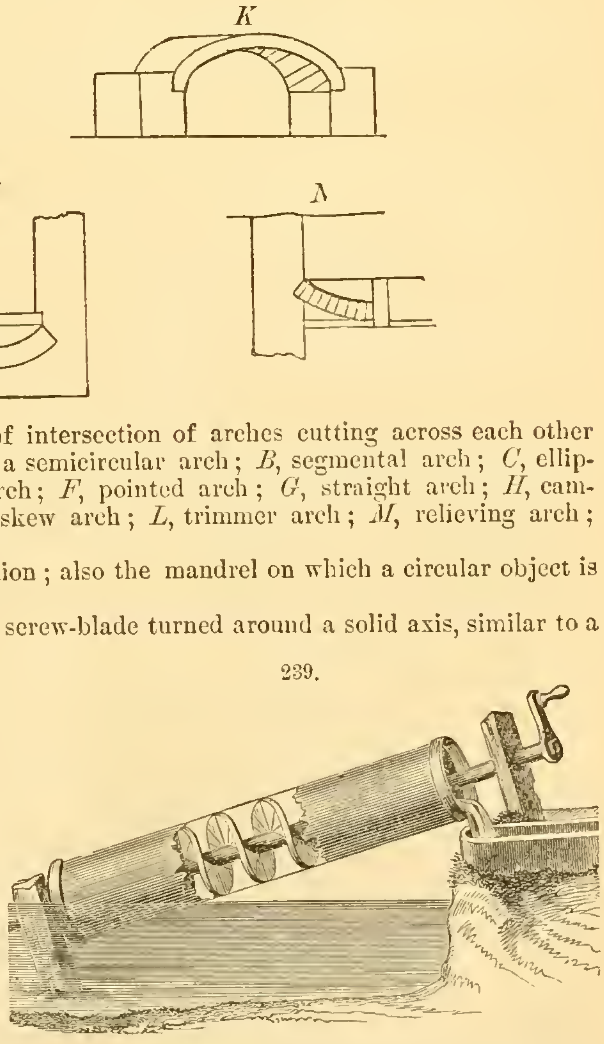



the haunches, called *spandrel*-backing. The line of intersection of arches cutting across each other transversely is called a *groin*. In Fig. 238, *A* is a semicircular arch; *B*, segmental arch; *C*, elliptical arch; *D*, three-centre arch; *E*, parabolic arch; *F*, pointed arch; *G*, straight arch; *H*, cambered arch; *I*, groined arch; *J*, fluing arch; *K*, skew arch; *L*, trimmer arch; *M*, relieving arch; *N*, inverted arch.

ARBOR. The axle or spindle of a wheel or pinion; also the mandrel on which a circular object is turned on the lathe.

ARCHIMEDEAN SCREW. This consists of a screw-blade turned around a solid axis, similar to a winding staircase, and inclosed in a hollow cylinder. When placed in an inclined position with the lower end in the water, the latter is caught between the screw-blades, and, the cylinder being turned in the proper direction, the water will be raised and discharged at the upper end. This apparatus may be usefully employed in raising water to a limited height (10 or 15 feet or less). By its aid one man may raise 40 gallons of water 10 feet high in a minute—a larger amount of work than can generally be done with hand-pumps, owing to friction in the latter. Fig. 239.

239.



ARCHITRAVE. In carpentry, borders fixed around the opening of doorways or windows for ornament, and also to conceal the joint between frame and plastering. When the base of the architrave is not of equal thickness throughout, but stepped back in the centre, it is said to be "double-faced." Architraves are generally built up of parts glued together, tongued and grooved if large. They are also made by machinery in one piece.

ARMATURE. See Magnet.

ARMING-PRESS. A machine used for embossing the back and sides of the cover of a book.

ARMOR. The problem for which a solution is sought in the cuirassing of ships of war, is, how best to protect them against the effects of the shock of the enormous projectiles which, thrown with an extraordinary energy from heavy guns of large calibre, will have to be resisted in future naval engagements, and against the convergent and simultaneous fire of other heavy guns but of smaller calibres. Up to 1862, experiments which involved the testing of plates ranging from a quarter of an inch to 8 inches in thickness, supported by various backings, yielded the following conclusions: 1. Good tough wrought-iron of high elasticity, but not necessarily of the highest ultimate tensile strength, is the best material for use in iron defenses; 2. Rolled iron, though not, perhaps, equal in resistance to the best hammered iron, has such great advantages as to cost, if used in simple forms, as to justify its use where lightness is not of extreme importance; 3. In plates or bars of ordinary dimensions, the resistance to cannon-shot varies in a proportion approximating that of the squares of the thickness of the bars or plates; 4. Rigid backing is immensely superior to elastic backing, so far as the endurance of the front facing is concerned, but the elastic backing deadens the effect of a blow upon any structure behind; 5. The larger the masses and the fewer the joints, the stronger the structure, so long as the limits of uniform and perfect manufacture are observed; 6. Revolving iron shields are practicable and safe; 7. The qualities necessary in an armor-plate are softness combined with toughness, or better expressed by the word ductility. Apparently, the purer and better the iron is, the more this quality is perceptible; any impurity or alloy appears to harden the metal and produce brittleness. The presence of either sulphur or phosphorus in the fuel is specially to be guarded against, as productive of red-shortness and cold-shortness in the iron. The presence of more than 0.2 per cent. of carbon in the armor-plates also appears highly prejudicial.

In 1865 a series of experiments were made by the British Government, to determine the relative penetrating effects of two shot on an iron plate, provided they strike with the same work or energy, notwithstanding the one may be heavy with a low velocity, and the other light with a high velocity. From these tests the following practical conclusions were drawn when the projectiles are fired direct: An unbacked wrought-iron plate will be perforated with equal facility by solid steel shot of similar form of head, and having the same diameter, provided they have the same *vis viva* on impact; and it is immaterial whether this *vis viva* be the result of a heavy shot and low velocity, or a light shot and high velocity within the usual limits of length, and so on, which occur in practice. An unbacked iron plate will be penetrated by solid steel shot of the same form of head but different diameters, provided their striking *vis viva* varies as the diameter, nearly, that is, as the circumference of the shot; and the resistance of unbacked wrought-iron plates to absolute penetration by solid steel shot and equal diameter varies as the square of their thickness nearly. These experiments also proved that, although, in the case of cast-iron, a light projectile moving with a high velocity will indent iron plates to a greater depth than a heavier projectile with a low velocity but equal work, it is not as necessary that there should be a high velocity when the projectiles are of a hard material, such as steel and chilled iron; and this result is much in favor of rifled guns, by enabling them to prove effective with comparatively moderate charges. If the plate is set at an angle, or the gun is fired obliquely at an upright plate, the shot has then a tendency to glance off and continue its motion in a new direction. The force with which the shot acting obliquely will strike is to that with which it would strike if acting directly as the sine of the angle of incidence is to unity. That is, the shot striking in a slanting direction may be supposed to have opposed to it a plate of a thickness equal to the diagonal formed by the line of direction. From the foregoing it may be demonstrated that a 4.5-inch unbacked plate, when fired at direct, requires a force represented by 28 foot-tons per inch of shot's circumference to insure penetration. When placed at an angle of 38° with the ground, the force required is increased to 73.9 foot-tons. An experiment of this nature, where solid steel shot of 70 lbs. weight and 6.34 inches in diameter were fired against a 4.5-inch plate, set at an angle of 52° with the vertical, showed that a force of 52.7 foot-tons per inch of shot's circumference was not sufficient to insure perforation, although the plates were cracked and opened at the back.

Since the determination of these results, both the calibre of guns and the thickness of armor-plates have greatly increased, and the latest trials—those of the 100-ton gun built for the Italian Government for use on the iron-clads Dandolo and Duilio—bring into remarkable relief the great superiority of steel as compared with iron plates, and at the same time yield results which could not be predicated upon those obtained with guns of smaller size.

The difficulties connected with the manufacture of iron plates of thicknesses greater than about 14 inches, and the consequent deterioration of the manufactured product, have hitherto led to a preference being given to armor built up of two plates, the thicker of which placed outside has sufficient strength to arrest, or nearly so, the heaviest projectiles at present forming the armaments of European navies (that is to say, calibres from 10 to 14 inches). The inner skin of the ship is thus protected by the second and thinner armor-plate, unless the shell should burst in the packing between the two plates, which would necessarily produce disastrous effects. The penetration of iron plates 14 inches in thickness requires an energy in the projectile of 230 foot-tons per inch of circumference; and only the heaviest calibres have hitherto been able to effect this, imparting, as they do, a striking energy of about this amount. So that, in the presence of 12-inch or 14-inch calibres, the adoption of this form of armor has been entirely justified.

In the experiments conducted at Spezia against targets, the projectiles from the 100-ton gun developed a mean striking energy of 550 foot-tons, and those of the 18-ton and 25-ton guns an energy of 170 foot-tons per inch of circumference. The outer iron plate of the compound target at Spezia was 12 inches thick, to perforate which, according to Noble's formula, would require a somewhat less force; and other trials with the 18-ton gun entirely confirmed this theory, the projectiles possessing only the force actually required to pierce the outer plate; this force being thus absorbed, the shots were of course stopped without producing any further destructive effects upon the target.

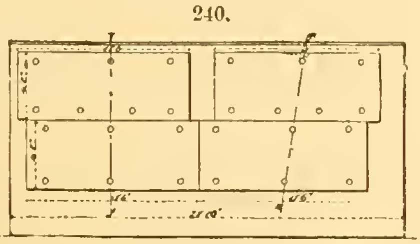
The projectiles fired with an energy of 230 foot-tons per inch of circumference, fired separately as well as simultaneously and converging, naturally produced effects very similar to those fired against the heavy 22-inch iron and the steel plates.

Invariably, however, totally different effects were produced by the projectiles from the 100-ton gun, which were fired, as has been already stated, with a velocity representing an average of 550 foot-tons per inch of circumference. The thickest iron plates forming the target should have been, according to Noble, easily pierced by the projectile endowed with such a striking force, and they were pierced completely. No reference need be made here to the compound target, which required only 275 foot-tons per inch to penetrate it; while the shot from the 100-ton gun, possessing twofold this force, had, as the experiments showed, a very large excess of power. On the other hand, the untouched steel plate, and the second one that had been injured by previous rounds, both completely stopped the projectiles from the 100-ton gun, and thus preserved the inner wall of the ship. The results of these rounds, and especially of that one fired against a fragment of the target much smaller than the original plate, and which, moreover, was only hanging to the backing, proves undoubtedly the superior resisting power of steel as compared with iron. Thus the same plate resisted one round from a 9.8-inch calibre gun, with a striking force of projectile of 162 foot-tons per inch of circumference; two simultaneous rounds from the 9.8-inch and 11-inch gun, with a striking force of about 170 foot-tons for each projectile, and one round from the 100-ton gun. After sustaining these three rounds, the backing was quite preserved without the skin of the ship sustaining serious injury. The pointed end of the projectile striking the iron plate acted like a wedge, rolled the fibres of the iron back laterally, and destroyed, by the vibration produced, the welding between the layers of iron forming the plate—an effect very visible at the Spezia trials; the projectile thus opens a way for itself through what can only be considered as a series of plates in close juxtaposition, but with only imperfect adherence.

Steel plates, which are constructed of a compact metal, are homogeneous, of an equal and constant resistance in all directions, and present quite a different nature of resistance to the pointed head of the projectile, which, striking a compact mass, cannot penetrate with the same facility, and, finding no fibre it can throw back, it is broken up, and tends to act like a wedge. In consequence of the rupture of the point, the shot is stopped, producing an effect which, it is true, damages the plate, but, thanks to the uniform compactness of the metal of the plate, the penetrating effects of the projectile are destroyed. Iron plates, even of enormous thickness, must remain powerless to resist such formidable assaults; and it would therefore appear that steel alone is capable of opposing itself to shocks of these tremendous magnitudes.

The targets referred to are shown in Figs. 240–243 the plates being mounted on framing representing that of the Duilio and the Dandolo. Figs. 240 and 241 are front elevations, showing the two wrought-iron plates of Cammell and Marrel respectively. The plates were each 11 feet 6 inches

240.



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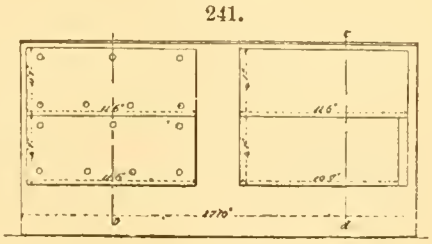

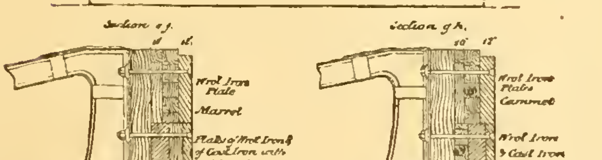

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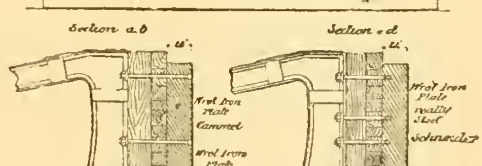


242.

long by 4 feet 7 inches deep, and 22 inches thick. In the target constructed of the steel plates of Messrs. Schneider, the upper plate was 11 feet 6 inches and the lower one 10 feet 9 inches long, and each 4 feet 7 inches deep by 22 inches thick. The backing consisted of two thicknesses of timber, the front balks being arranged in horizontal layers and the rear vertically. The inner skin of each target consisted of two ¾-inch wrought-iron plates. Figs. 242 and 243 show sections through the centre of each plate. From these the methods of bolting through will be seen. A portion of the target, shown in the elevation at Fig. 240, consisted of one of Marrel's 12-inch wrought-iron plates of the same length and depth as before. Behind this was first a wood backing arranged horizontally, then another of Marrel's plates 10 inches thick, and then the vertical wood backing and skin. The lower part of this target was made up of a face-plate of wrought-iron 8 inches thick, backed with vertical timbers, behind which was a 14-inch chilled cast-iron plate, and to its rear the vertical timbers and iron skin-plates. The remainder of this target had at the upper part a 12-inch wrought-iron face-plate by Cammell, a thickness of horizontal timbering, and a 10-inch wrought-iron plate by the same maker, the whole being backed as before. The lower portion was made up of an 8-inch wrought-iron face-plate with a 14-inch cast-iron plate immediately behind it. The plates were backed with horizontal and vertical timbers and two ¾-inch wrought-iron plates as before. Sections of the targets shown in Fig. 241 are given in Fig. 242, and in each case it will be seen that the targets are further

backed by framing representing that of the ships, the deck-beams, however, being bent downward toward the ground, and their ends being well strutted. Wrought-iron stringers were also introduced in the timber backing.

It will be seen from the Spezia trials that steel may stop shot which would penetrate iron. At the same time, steel is much more liable to be destroyed by splitting, and to snap its bolts. The statement may be put in this way: The shot may be stopped by expending its work in fracturing steel when it would penetrate iron, because the steel, by transmitting the shock through its mass, absorbs it chiefly in making cracks in various directions, while soft iron does not transmit the blow, but receives the whole work on the immediate locality of the point of impact, and so must yield more easily. In order to keep intact the steel protection when the plate becomes disintegrated gradually under the blows of comparatively small shot, the adoption of an outside coating or binder of wrought-iron plates of great width and extent has been proposed, into which the bolts would hold, with massive steel plates behind it. It is claimed that much cracking and splitting of the steel might then take place without serious displacement of fragments. Tests of plates constructed in view of the foregoing have been made, the general results of which show a decided advantage in placing iron behind the steel. The "compound plates" tested by the Admiralty (Portsmouth, 1877)* were of four types: 1. Cammell's sub-carbonized plate of solid steel, containing but 13 per cent. of carbon. This split, although the test (impact of 250-lb. Palliser shot from 12-ton 9-inch muzzle-loading rifle-gun at 30 feet range) was well withstood. 2. A combined iron and steel plate, composed of steel (.64 per cent. carbon) 4 inches thick, backed by 5 inches of wrought-iron, was easily penetrated. 3. A sandwiched plate, composed of three-quarter inch of wrought-iron, 6½ inches of steel, and 1¾ inch of iron, likewise failed. 4. A plate of Whitworth compressed steel, in which hardened steel screw-plugs were inserted, cracked under the impact, the plugs tending to produce this effect. It may be added that the whole question of armor-plating is (1878) undergoing revolution, and that no completely efficient system has ever yet been discovered. The problem, after all the enormous outlay spent in attempts toward its solution, has virtually narrowed itself down to whether it were better to adopt iron armor, which does not fissure, but allows the projectiles to penetrate; or steel armor, which successfully resists the penetration of the shot, but is itself broken up.

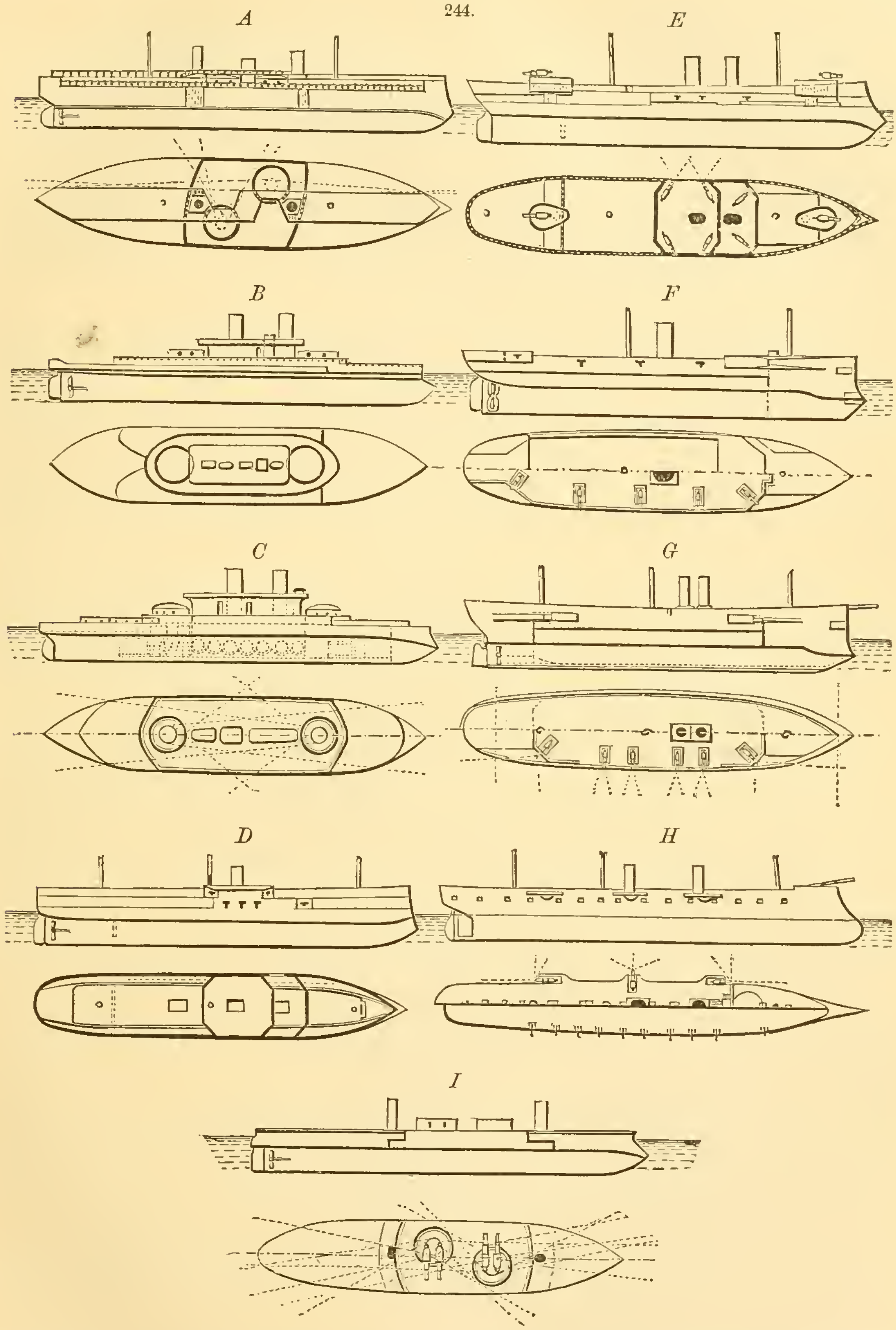
*The Modern Types of Armored Vessels.*—The Inflexible, *A*, Fig. 244. The protected portion of the ship is confined to the citadel or battery, within whose walls are inclosed all the vital parts of the vessel. The vessel measures 110 feet in length, 75 feet in breadth, and is armored to the depth of 6 feet 5 inches below the water-line, and 9 feet 7 inches above it. The armored portion is included between the two shaded vertical bands in the figure. The sides of the citadel consist of an outer thickness of 12-inch armor-plating, strengthened by vertical angle-iron guides 11 inches wide and 3 feet apart, the space between them being filled in with teak backing. Behind these girders, in the wake of the water-line, is another thickness of 12-inch armor, backed by horizontal girders 6 inches wide, and supported by a second thickness of teak backing. Inside this are two thicknesses of 1-inch plating, to which the horizontal girders are secured; the whole of the armor-backing and plating being supported by and bolted to transverse frames 2 feet apart, and composed of plates and angle-irons. It will thus be seen that the total thickness of armor at the water-line strake is not less than 24 inches. The armor-belt, however, is not of uniform strength throughout, but varies in accordance with the importance of the protection required and the exposure to attack. Consequently, while the armor at the water-level is 24 inches in two thicknesses of 12 inches each, above the water-line it is 20 inches in two thicknesses of 12 inches and 8 inches, and below the water-line it is reduced to 16 inches in two thickness of 12 inches and 4 inches. The teak backing with which it is supported also varies inversely as the thickness of the armor, being respectively 17 inches, 21 inches, and 25 inches in thickness, and forming, with the armor with which it is associated, a uniform wall 41 inches thick. The depth of armor below the load water-line is 6 feet 5 inches; but as the vessel will be sunk a foot on going into action, by letting water into its double bottom, the sides will thus have armor protection to the depth of 7 feet 5 inches below the fighting-line. The outside armor is fastened by bolts 4 inches in diameter, secured with nuts and elastic washers on the inside. The shelf-plate on which the armor rests is formed of ½-inch steel plates, with angle-iron on the outer edge 5 inches by 3½ inches by nine-tenths of an inch. The armor on the fore bulkhead of the citadel is exactly the same in every respect as that on the sides, but the armor of the rear bulkhead is somewhat thinner, being of the respective gradations of 22, 18, and 14 inches, and forming, with the teak backing, which is 16, 20, and 24 inches, a uniform thickness of 38 inches. It may also be useful to mention that before and abaft the citadel the frames are formed of 7-inch and 4-inch angle-irons, covered with $\frac{9}{16}$-inch plates. The total weight of the armor, exclusive of deck, is 2,250 tons, and the total weight of armor, inclusive of deck, is 3,155 tons.

The most singular feature in the design of the ship is the situation of the turrets. All turrets are placed on the middle line—an arrangement which, though advantageous in some respects, possesses this signal disadvantage, that in double-turreted monitors only one-half of the guns can be brought to bear on the enemy—which rise up on either side of the ship *en échelon* within the walls of the citadel, the forward turret being on the port-side and the after turret on the starboard-side, while the superstructures are built up along a fore-and-aft line of the deck. By these means the whole of the four guns can be discharged simultaneously at a ship right ahead or right astern, or on either beam, or in pairs, toward any point of the compass. The walls of the turrets, which last have an internal diameter of 28 feet, are formed of a single thickness of 18 inches, with backing of the same thickness, and an inner plating of 1 inch in two equal thicknesses.

The Thunderer, *B*, Fig. 244. Here the height of the side-armor above and below water is shown. The position of the armored deck is indicated by the line along the upper edge of the side-armor.

* *Engineering*, xxxiv., 625.

244.




The Dreadnought, *C*, Fig. 244. The citadel is 184 feet in length, and the height between-decks is 7 feet 6 inches. It is armored with solid plates 11 inches thick, except at the ends and abreast the bases of the turrets, where the thickness is increased to 13 and 14 inches. The armor-belt, which is carried entirely around the vessel, is 11 inches thick on the water-line, tapering to 8 inches at 5 feet below water, where it stops. It also tapers above water, fore and aft of the citadel as well as toward the ends. This armor-belt, fore and aft the fighting part of the ship, rises only 4 feet above water, and is intended solely to protect the vital portion of the hull. The turret-deck is plated with two courses of $1\frac{1}{2}$ and 1 inch iron respectively, and the main berth-deck below is also plated with the same thickness of metal fore and aft of the citadel.

The turrets rise through the citadel-deck to a height of 12 feet from the base or revolving deck-platform inclosed by the citadel. The diameter of each turret inside of framing is 27 feet 4 inches,

the depth of the framing being 10 inches. They are built up with two courses of plates and two courses of teak, in the following manner: first, the shell or wall consists of two ¾-inch plates, bolted together and riveted to the framing; on the exterior of this shell is a teak backing 6 inches thick; on this backing armor-plates 7 inches thick are secured; next, teak backing 9 inches thick is fastened on; finally, armor-plates outside of all, 7 inches thick—all securely bolted together. The plates were rolled at Sheffield, and curved to templates, drilled and prepared for their places.

The Alexandra, *D*, Fig. 244. The sills of the main-deck ports are 9 feet and those of the upper-deck ports more than 17 feet above the water. The water-line is protected by a belt having a maximum thickness of 12 inches, and it will be seen that the armor forward is carried down over the ram, both to strengthen the latter, and to guard the vital parts of the ship from injury by a raking fire from ahead, at times when waves or pitching action might expose the bow. The machinery, magazines, etc., are similarly protected against a raking fire from abaft by an armed bulkhead 5 inches thick. The batteries are protected by armor only 8 inches thick below and 6 inches above; the total weight of armor and backing is 2,350 tons.

The Téméraire, *E*, Fig. 244. This vessel carries her upper-deck armament in two fixed open-top turrets, the forward one protected by 10-inch, the after one by 8-inch armor. Like all belted ships, the Téméraire has weak places in her water-line; but amidships, over the most vital parts, she has 11-inch armor (against 12-inch in the Alexandra), reduced very slightly above and below. At the bow, to guard against exposure to raking fire in pitching, the armor is carried down over the point of the ram, and similar protection is gained for the magazines, etc., against raking fire from aft, by an armored bulkhead across the hold (shown in the sketches); this is plated with 5-inch armor. The deck at the level of the top of the belt outside the main-deck battery is 1½ inch thick. The hull, which has the usual double bottom, and is divided into very numerous water-tight compartments, is built on the well-known bracket-frame system, and it is sheathed externally with wood covered with zinc. The weight of the armor and backing is about 2,300 tons, or nearly the same as in the Alexandra.

The Shannon, *F*, Fig. 244. There are several interesting peculiarities in the construction of this vessel. The guns which are to fight upon the broadside are on an open deck, and all without protection of armor. The armor is limited to a belt extending around the vessel at the water-line; this belt is not tapered toward the bow, as is usual, but ends abruptly 60 feet short of it, at an armored bulkhead 9 inches thick, which extends across the vessel at this point, and descends 5 feet under water. Forward of this bulkhead the armor takes the form of a submerged deck 5 feet below water, running forward and sloping to 10 feet at the stem. The plating of this deck is 3 inches thick. The deck aft of this armor-bulkhead is of iron 1½ inch thick, covered by wood; the hatches passing through it are protected by shell-proof gratings. The armor-bulkhead already referred to—that across the bow of the vessel, 60 feet from the stem—rises to a height of 20 feet above the water-level to the top of the forecastle; and it here turns at the sides, extending aft and embracing the forecastle with arms 26 feet long on both sides. It thus guards both decks against raking fires from ahead, and creates an armored forecastle, open at the rear, and carrying two 18-ton bow-guns. Within this armored forecastle are the instruments for communicating with the engine-room, the helm, and the battery. In other respects the ship is unarmored.

The armor-belt referred to is 9 feet deep, 5 feet of which are under water and 4 feet above water. It is put on in 12-foot lengths, and extends from 4 inches under the counter to 60 feet from the stem. The thickness at the water-line is 9 inches, tapering below as well as above the water.

The Nelson and Northampton, *G*, Fig. 244. In these vessels the protecting armor consists of a belt on the water-line of about 181 feet in length amidships; this belt is 9 feet deep, 4 feet above water and 5 feet under water. It is put on in two strakes; the upper plates are 9 inches thick on a 10-inch backing of teak, and the lower plates are tapered to 6 inches thick, supported by a teak backing 13 inches thick. Extending across the ship at each end of this armor-belt there is an armor-bulkhead; it starts at the bottom of the armor-belt, 5 feet under water, and extends to the upper deck, having in all a depth of 22 feet. Its thickness is 9 inches above water, tapering to 6 inches at the bottom. Between the main and upper decks these bulkheads are shaped to form corner ports at the fore and after ends of the battery. Between the armor-bulkheads, and at the upper level of the armor-belt, the lower deck is formed throughout of 2-inch plates, by means of which protection is afforded to the machinery, boilers, magazines, etc. A peculiar feature is the horizontal armor as here applied. For about 57 feet at the fore-end there is an armor-deck. This deck is 2 inches thick, and it is 5 feet under water at the junction with the armor-bulkhead, but inclines deeper toward the stem, and terminates forward in the ram. There is likewise an horizontal armor-deck of the same thickness and depth under water, extending from the after armored bulkhead to the stern. These submerged armor-decks are intended to protect the lower part of the ship fore and aft of the armored bulkheads, especially the steering-gear provided for emergencies.

The Duquesne (French), *H*, Fig. 244. This vessel is a cruiser of the rapid type, and is designed for 17 knots per hour at sea. The frames, bulkheads, beams, and all interior parts, also masts, are composed of steel; but the outside plating of the hull is entirely of iron, and the bottom is sheathed with 2 layers of teak planks, in all 7 inches thick, and coppered, put on in a similar manner to the system of the English, except that, to insulate the iron from the copper, thick layers of marine glue have been placed between the iron hull and the teak planks, also between the teak and copper.

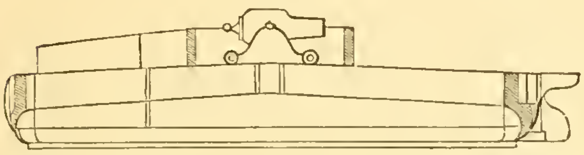
The Dandolo (Italian), *I*, Fig. 244. There is a central armored citadel or compartment, 107 feet in length and 58 feet in breadth, which descends to 5 feet 11 inches below the load water-line. It protects the machinery and boilers, the magazines and shell-rooms, and a portion of the machinery for working the turrets and guns. Forward and aft of this citadel, the decks, which are 4 feet 9 inches under water, are defended by horizontal armor. Over this citadel is built a second central armored compartment, which incloses the bases of the turrets and the remaining portion of the mechanism

employed in loading and working the guns. Lastly, above this second compartment rise the two turrets. The turrets are placed at each end of the central armored citadel—not in an even line with each other, but diagonally at opposite corners of it, with the centres at the distance of 7 feet 8 inches from the longitudinal centre-line of the vessel, so that one turret is on the starboard side and the other on the port side. The effect of this arrangement is to render possible the discharge of three guns simultaneously in a direction parallel with the keel. Only the central portion of the ship and the two turrets will be protected by vertical armor.

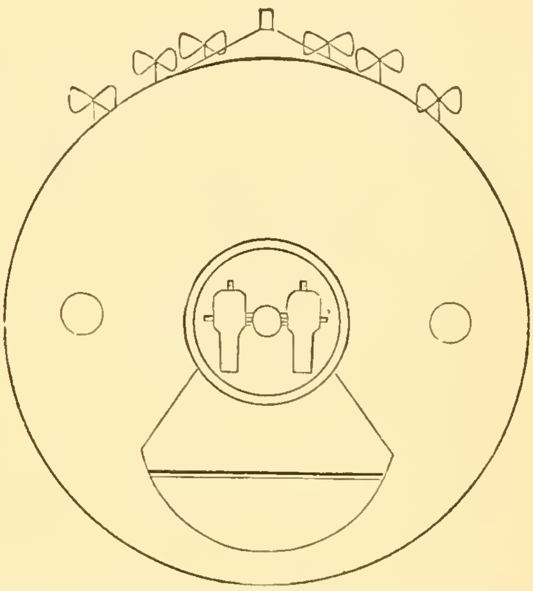
As regards the armor of the central portion of the vessel, the thickness at the water-line is 22 inches. The decks are protected by horizontal armor of iron and steel, the former being under the latter. The armor of the turrets will be composed of solid plates 19 inches in thickness, resting upon teak backing.

Admiral Popoff and Novgorod (Russian), Figs. 245 and 245 A: Circular iron-clads or Popoffkas

245.



245 A.



These vessels are circular only in one sense; i. e., their horizontal sections only are circular, or, in other words, they have circular water-lines. The departure from a circle is a small extension or protuberance at the stern for the purpose of facilitating the arrangement and working of the rudder and steering-apparatus. It follows as a consequence from the circular form of water-line, that all the radial sections are alike; the bottom of the vessel is an extended plane surface, which is connected with the edge of the deck by a quadrant of a small circle. With this form of section great displacement is obtained on moderate draught of water. The deck of the circular ship is formed in section with such curvature as to give in a ship of 100 feet in diameter a round-up of about 4 feet.

*Types of Armor Plating—Laminated Armor.*—In American iron-clads this type of armor has been largely used. It consists of consecutive plates averaging 1 inch in thickness, but backed, as in some of our monitors, by armor-stringers or plank-armor of small breadth and moderate thickness. Experiments made by the English Admiralty proved this laminated armor to be far inferior to solid armor in power of resistance, and that no amount of strengthening can compensate for the defects of the system. The resistance of single armor-plates, shown by direct experiment for all thicknesses up to 5½ inches to vary as the square of the thickness, does not obtain for laminated armor. For example, a 4-inch solid plate would be 16 times as strong as a 1-inch plate, but would not be four times as strong as four 1-inch plates riveted together, although it would be much stronger than the laminated structure. From actual experiment, it also appears that projectiles arrested by a 4-inch solid plate easily penetrated 6 inches of laminated plates.

*Elastic-Backed Armor.*—It has already been noted that a rigid backing for armor is in all respects preferable to an elastic one; and this conclusion is substantiated by experiments upon a large variety of types of armor, using a number of different substances as support. Millboard in thicknesses of 15 inches, tissues of wire ropes 14 inches thick, India-rubber and pine, India-rubber and oak (1 inch rubber and 20 inches oak, afterward 4 inches of rubber and same thickness of wood), have all been tried, and have failed. A similar result was obtained with a target of four 1-inch wrought-iron plates, and four sheets of rubber 1 inch thick, backed by 20 inches of solid oak; and it was conclusively settled, by comparative tests, that India-rubber serves no useful purpose in causing (as was supposed might be the case) the shot to recoil. A large iron boiler 10 feet in diameter was packed with wool at Shoeburyness, in 1864, and subjected to the shot of a 68-pounder and a 111-pounder Armstrong gun at 100 yards range. The shot passed through 11 feet of wool, the iron caisson, and buried themselves in 12 feet of solid earth. Five bales of hog-hair, backed by 4-inch plank, aggregating a thickness of 3 feet 3½ inches, have been easily pierced by a 38-pound rifle-shot. The advantages of wood backing are not so much that it adds material strength or resistance to the armor-plate, but—1. It distributes the blow. 2. It is a soft cushion, to deaden the vibration and save the fastenings. 3. It catches the splinters. 4. It still holds the large disks, that may be broken out of a plate, firmly enough to resist shells. A solid backing of wood of from 2 to 4½ times the thickness of the iron unquestionably adds to the resistance, and, when divided into a cellular form by iron edge-pieces or girders, as in the Chalmers target, offers great support, and prevents the distortion of the plates by buckling.

*The Armor of American Iron-clads* may be briefly summarized as follows: The original monitor had her hull protected by 5 layers of 1-inch plate, diminishing first to 4 inches and then to 3 inches in thickness below the water-line. Her turret was built of 8 layers of 1-inch iron. The Passaic class of monitors have armor of the same thickness as the first monitor, with 39 inches of wood backing. The Canonicus class have 5 layers of 1-inch plates, supported by 2 armor-stringers let into 27 inches of wood backing. Their turrets have 11 layers of 1-inch plates. The Miantonomoh

and the Monadnock, which are wood-built, are protected much like the Canonicus. The Puritan and the Dictator have 6 layers of 1-inch plates on their sides, with 42 inches of wood backing. Their turrets are 15 inches thick, made up of two drums, with segments of wrought-iron hoops 5 inches thick, placed between the drums, which are composed of layers of 1-inch plates. In the Kalamazoo class the total thickness of hull-armor is 6 inches, made up of 2 layers of 3-inch plates, backed by 30 inches of oak, still further strengthened near the water-line with 3 armor-stringers 8 inches square, let into the backing, and only a few inches apart. This is by far the most formidable armor carried by any of our monitors; and while there are in some places 14 inches of iron, there is no part of it nearly so strong as it would be with that thickness of solid plates. The turrets of the Kalamazoo are 15 inches thick, like those of the Dictator, but none of them have any backing or wood about them. The rapid diminution in thickness of armor on these vessels is a serious defect, leaving no ground for comparison with corresponding English ships. The Dictator, for instance, 2½ feet below the water-line, has but two 1-inch plates, and at 3 feet only one. Though generally unfit for cruisers, the monitors are well adapted to coast and harbor defense.

*Works for Reference.*—"A Treatise on Ordnance and Armor," A. L. Holley, 1865; "Report of Secretary of the Navy on Armored Vessels," Washington, 1864; Capt. Noble's "Report on the Penetration, etc., of Armor-Plates," 1876; "System of Naval Defenses," Eads, 1868; "Our Iron-clad Ships," and "Shipbuilding in Iron and Steel," by E. J. Reed, London, 1869; "Reports of the Committee Appointed by the Lords Commissioners of the Admiralty to Examine the Designs upon Ships-of-War which have recently been Constructed," London, 1872; "La Marine cuirassée," by M. P. Dislère, Paris, 1873; and "Reports of the Secretary of the Navy"—Report of Chief-Engineer J. W. King, U. S. N., on European Ships-of-War, etc., Senate Ex. Docs., No. 27, Washington, 1877 (from which copious extracts are embodied in the foregoing).

ARMOR, SUBMARINE. See Diving.

ARRIS. The angle formed by the meeting of two surfaces not in the same plane. A piece of square timber sawed diagonally is said to be cut arriswise. The term is applied to tiles laid diagonally.

ARRIS-PIECES. The portions of a built mast between the hoops.

ARTESIAN WELL. See Well-Boring.

ARTIFICIAL STONE. See Concrete.

ARTILLERY. See Ordnance.

ASBESTOS. A mineral fibre composed of silicate of magnesia, silicate of lime, and protoxide of iron and manganese. Mineralogically, the name is given to the fibrous varieties of tremolite, actinolite, and other species of hornblende, excepting such as contain alumina, and also to the corresponding mineral pyroxene. It exists in vast quantities in the United States, in various parts of Great Britain, Hungary, Italy, Corsica, and the Tyrol. To various kinds of asbestos have been applied the names "mountain leather," "mountain cork," "amianthus," and "chrysolite," and certain other minerals having characteristics resembling those of asbestos are described as asbestoid, asbestiform, and as lamellar-fibrous. The chief characteristics of the mineral upon which its value depends are its indestructibility by fire and its insolubility (except for a few varieties) in acids; secondly, its peculiar fibrous quality. The material is obtained from the mines, in forms ranging from bundles of soft, silky fibres to hard blocks. The blocks may be broken up and separated into fibres, which, like those naturally obtained in that state, are extremely flexible, admit of great extension in the direction of their length without cracking, are greasy to the touch, and very strong. The fibre obtained in New York and Vermont varies in length from 2 to 4 inches, and resembles unbleached flax when found near the surface, but when taken at a great depth it is pure white.

One of the first applications of this mineral was the manufacture of incombustible cloth, the fabric being woven of asbestos and vegetable fibre. The latter was employed on account of the shortness of the asbestos fibre. The vegetable substance was afterward burned out, leaving the incombustible texture. Another early utilization was in lamp-wicks, for which purpose it is still used by the Greenlanders. Asbestos has also been woven into a fabric for shrouds. At the present time it has many important utilizations, and as it is practically an almost undeveloped substance, others will doubtless eventually be discovered.

A paper is manufactured containing about one-third its weight of asbestos. It burns with a flame leaving a white residue, which, if carefully handled, retains the shape of the sheet. Any writing in common ink upon it remains legible even after the organic substance has been consumed. An asbestos pasteboard is made in Italy which has withstood the heat in a furnace-fire indefinitely. Boxes of this material are now made to serve as fire-proof receptacles for valuable documents.

Asbestos cloth is worn by firemen in Paris for protective purposes. Hats and coats are made of it, and with gloves of asbestos the wearer may handle a firebrand or frozen hose without danger of burning or freezing the fingers. Moreover, the hose may be protected from the action of frost by jacketing the couplings with asbestos cloth, or may itself be manufactured from that material. In Siberia, purses and gloves are produced from the asbestos fabric. In Italy, lace has been made from it. According to Sage, in China, sheets of paper 19.2 feet long, and entire webs of cloth, have been prepared from the mineral. Such fabric (paradoxical as the statement appears) is washed by putting it in fire, which burns out the foreign matters.

Besides being one of the most refractory substances, asbestos is probably one of the most perfect non-conductors and insulating mediums known. Like all non-conductors, it takes protracted exposure to heat to change its temperature; but, once hot, it in like manner tenaciously retains heat. This fact prevents its being used successfully for fire-proof safes. It has been applied to the construction of refrigerators, and a patent in the United States covers its utilization in a refrigerator-car. Asbestos is also used as an insulating material in electrical apparatus, as a means of absorbing illuminating oil and preventing its distribution in case of fracture of the lamp, and, combined with mercury, fats, soapstone, plumbago, and oils, as a lubricant. It is also utilized as a means of burning petroleum oil

under steam-boilers, a thin layer of the mineral being placed on a suitable grate and soaked with the oil, the vapor from which is ignited, producing an intense heat. So perfect is the non-conducting nature of the asbestos, that a sheet of paper placed beneath the oil-soaked layer remained in the furnace uninjured, despite the fierce heat above. It is also proposed to use asbestos as a lining for blast-furnaces, particularly adapted for employment where the metals or ores contain sulphides, the effects of which the mineral resists.

A New York manufacturer of roofing, etc., has patented a large number of applications of asbestos. Combined with felt and other materials, he employs it for roofing purposes, where its incombustible nature tends to prevent the possible conflagration of the roof by sparks from chimneys or from adjacent burning buildings. The same manufacturer has devised an asbestos concrete, asbestos-lined hair-felt for boilers, and an especial cement, in which layers of asbestos are inserted for the same purpose. He also uses the ground mineral as a body for oil-paint, and incloses the fine, short fibre in hollow tubes of webbing to adapt it for use as packing.

The employment of asbestos as steam-packing is probably its most important mechanical application. The credit of its suggestion for this purpose is due to Mr. St. John Vincent Way, C. E. Referring to the value of the material, in a paper read before the Institution of Engineers and Shipbuilders in Scotland, he says: "The packing used for piston and valve rods or spindles has three prime elements of destruction to contend with, namely, an elevated temperature, friction, and moisture; and one of them only—namely, friction—has any appreciable effect on asbestos packing, when the mineral is pure and properly prepared. No matter how high the temperature of the steam, how rapid the stroke of the piston, or how great the steam pressure, the packing seems to be unaffected by these conditions. In America, where the new packing was first used, some of it was taken from the piston-rod stuffing-box of a locomotive-engine, after having been in another engine at constant work for three months, with steam at 130 lbs. pressure per square inch, and making an average daily run of 100 miles, including Sundays; and, as can be seen by the sample shown, the fibre, with the exception of being discolored by oil and iron, is just as flexible and tenacious as originally. After having been once disintegrated, it appears impossible so to pack or mat the fibres together that they are not easily separated by the fingers."

Asbestos packing, according to Mr. P. L. Simmons, in whose work on "Waste Products and Undeveloped Substances" (London, 1876) a valuable paper on this subject appears, has been in use on the Anglia, of the Anchor Line of transatlantic steamships, for 16 months, during which period the vessel steamed over 98,000 miles. The chief advantages possessed by asbestos as packing seem to be its freedom from the slow carbonization which occurs in hemp, and its retention of elasticity, thus always keeping tight joints.

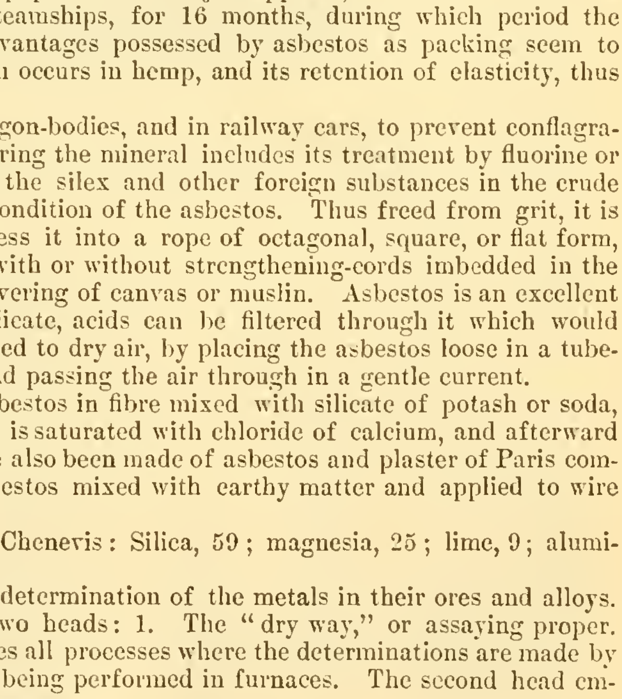
The utilization of asbestos in boats, boxes, wagon-bodies, and in railway cars, to prevent conflagration, has been suggested. A late plan for preparing the mineral includes its treatment by fluorine or hydrofluoric-acid gas, to dissolve and eliminate the silex and other foreign substances in the crude material, and thus to secure a pure and fibrous condition of the asbestos. Thus freed from grit, it is proposed to reduce it to a flock, and then compress it into a rope of octagonal, square, or flat form, and with a dense and adhesive structure, either with or without strengthening-cords imbedded in the surface, or, as the equivalent of such cords, a covering of canvas or muslin. Asbestos is an excellent material for the chemist as a filter. Being a silicate, acids can be filtered through it which would destroy ordinary filtering material. It is also used to dry air, by placing the asbestos loose in a tube-like sponge, moistening it with sulphuric acid, and passing the air through in a gentle current.

An asbestos building-stone is composed of asbestos in fibre mixed with silicate of potash or soda, and pressed in moulds. After the block is set it is saturated with chloride of calcium, and afterward washed in water. Asbestos building-blocks have also been made of asbestos and plaster of Paris combined with sawdust, coke-dust, or cinders. Asbestos mixed with earthy matter and applied to wire gauze has been suggested for walls.

The following analysis of asbestos is given by Chenevis: Silica, 59; magnesia, 25; lime, 9; alumina, 3; water, iron, etc., 4: total, 100.

ASSAYING. This art has for its object the determination of the metals in their ores and alloys. The methods employed may be classed under two heads: 1. The "dry way," or assaying proper. 2. The "wet way," or analysis. The first includes all processes where the determinations are made by the direct action of heat, the various operations being performed in furnaces. The second head embraces the estimation and separation of the elements by the action of solvents, aided or unaided by heat, the use of furnaces not being essential; and it does not, therefore, come under consideration, save in speaking of the methods employed for parting and refining gold and silver used principally in the assay offices and government mints.

246.



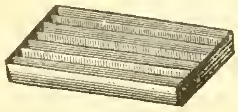
I. Treatment of Ores.—The various operations which may take place in making the assay of any ore are: 1. Preliminary testing of the ore. 2. Preparation of the ore, sampling, pulverizing, etc. 3. Weighing out the ore and reagents. 4. Calcination and roasting. 5. Reduction and fusion. 6. Scorification and cupellation. 7. Inquartation and parting of the silver and gold bead. 8. Weighing beads or bullion.

1. *The preliminary determination of the ore* is effected either by the eye or the blowpipe, or else by making up a charge of ore, if it be gold or silver, with litharge and soda, fusing the mixture in a hot fire, and weighing the resulting button of lead. This determines what is called the "reducing

power" of the ore, and enables the assayer to calculate with exactness the proper charge for the regular assay.

2. *Preparation of the Ore.*—All ores must be pulverized and sampled before they can be assayed. For this purpose, the following tools or apparatus will be found convenient:

247.



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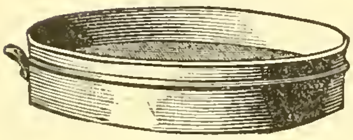

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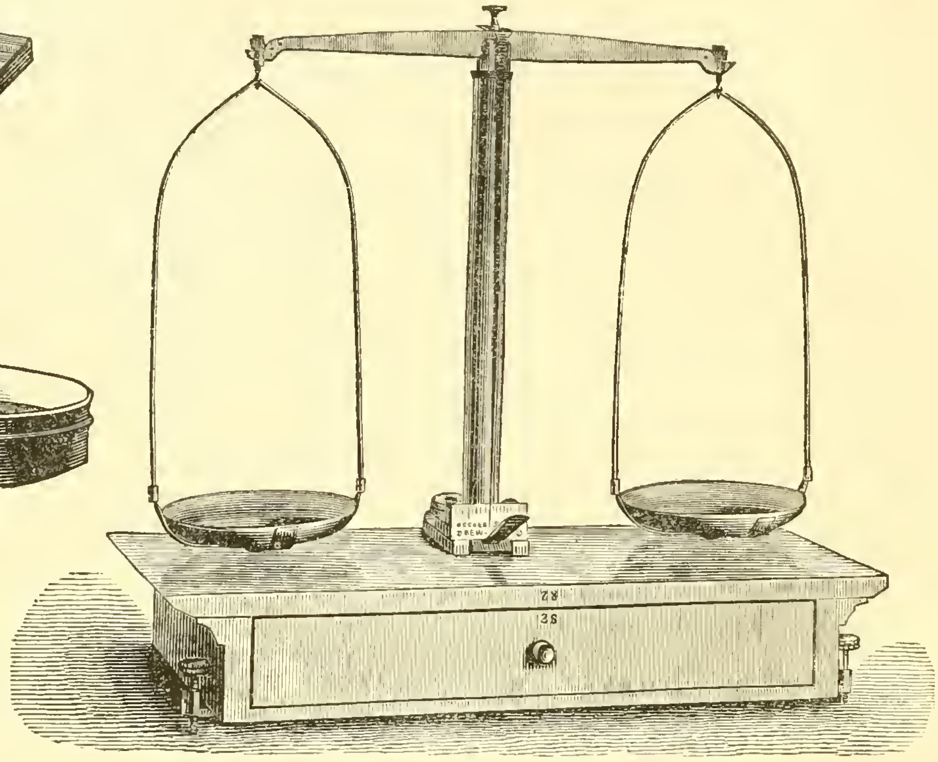
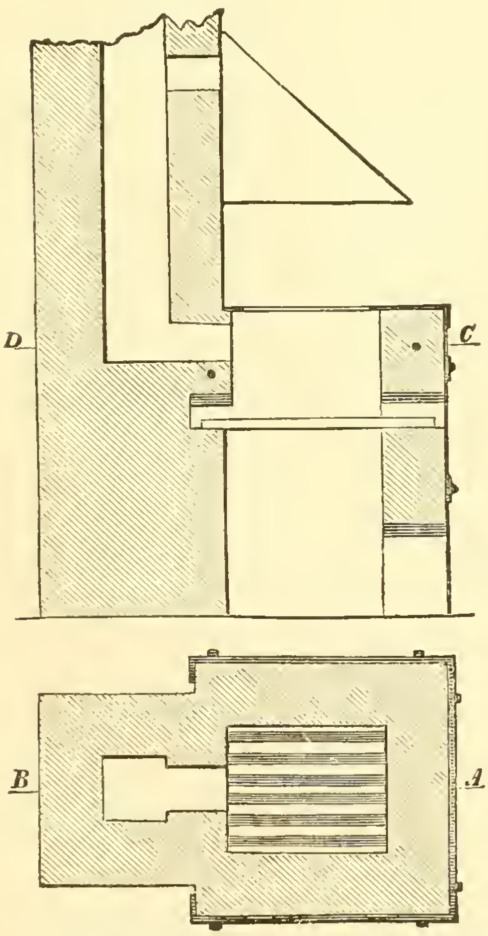
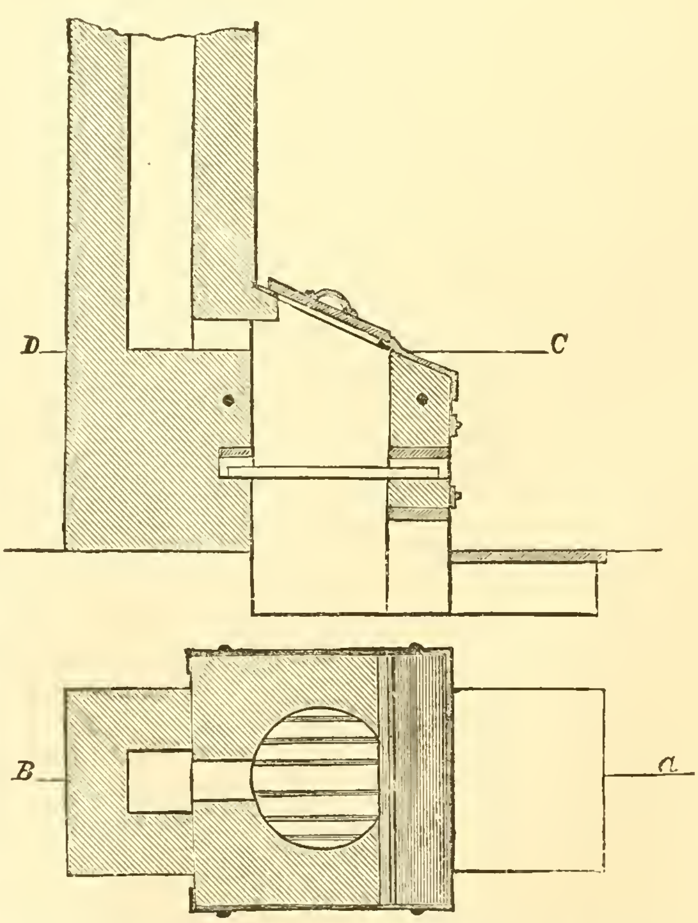


1. An iron mortar and pestle, and, if much ore is to be pulverized, a grinding plate and rubber, as shown in Fig. 246. The plate is a flat iron casting $18 \times 24$ inches, and 1 inch thick, the surface used

250.




251.

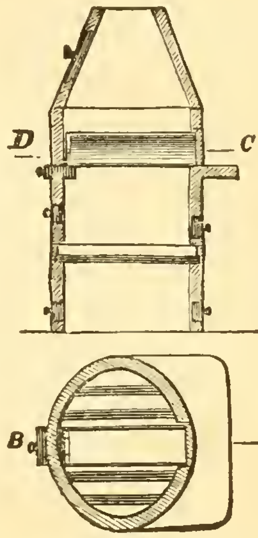



being planed smooth. The rubber or grinder is a piece of cast-iron, $4 \times 6$ inches square, $1\frac{1}{4}$ inch thick in the middle, and seven-eighths of an inch at the ends; thus giving a slightly convex surface,

which should be true on the board at all points. To conduct the operation, place the left hand upon the rubber, throwing the weight of the body upon it, grasp the handle with the right hand, and move

252.

253.




the iron rubber back and forth, depressing the handle when pushing forward and raising it in drawing back.

2. A tin sampler, shown in Fig. 247. It consists of a series of troughs arranged in a row and fastened together at equal distances by a tin strip soldered on their ends. A shovelful of ore, emptied by a series of shakes upon them, is just half caught by the troughs, the other half going through the openings between. By repeating this operation, the size of the sample can be reduced to any extent desired.

3. A box with a sieve fitting into it, as represented in Fig. 248. The sieve is a tin frame with gauze of any desired mesh soldered to it, and fits tightly in the box. The advantage gained by its use is that in sifting the pulverized ore there is no dust; the fine material, being passed through the sieve, is kept from flying around. All of the sample should be passed through the sieve. The size most convenient is 8 inches in diameter, the box 2 inches deep, and the rim of the sieve $1\frac{1}{2}$ inch, fitting about three-quarters of an inch into the box.

The ore is first broken into small pieces, and then cracked in the mortar until it is reduced to a coarse sand, when it is transferred to the plate and rubbed down. If the sample is a large one, the tin sampler is used to divide it after breaking down the lumps in the mortar.

4. The balance for weighing out ore for assay, and the buttons of the base metals, is shown in Fig.

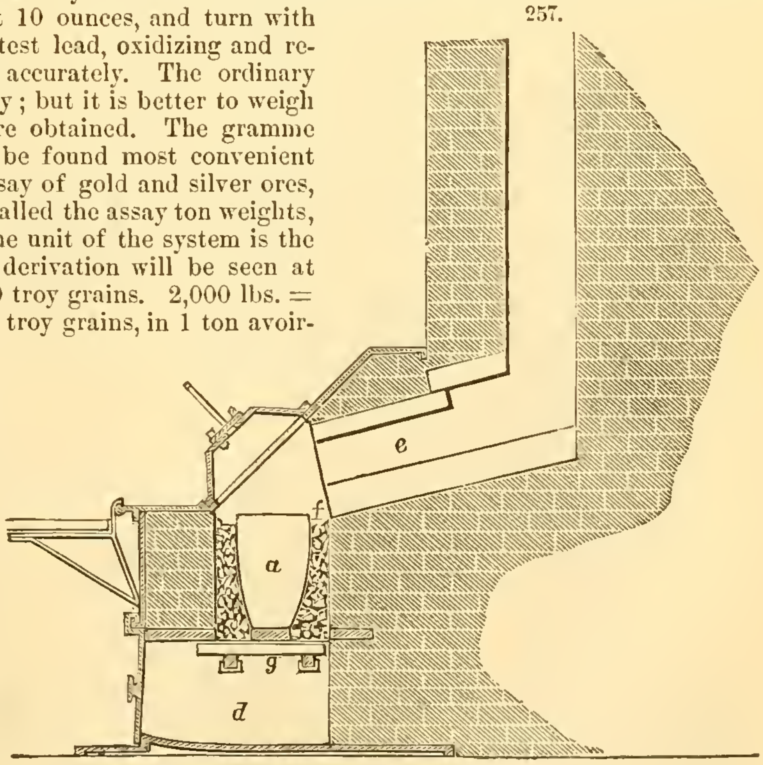
254.

256.

255.

249. This balance should take 10 ounces in each pan, turn with one-twentieth of a grain, and be provided with movable pans, level, and set-screws for adjusting. It is generally placed on a box, with drawer for weights. For weighing reagents and fluxes, hanging scales will be found useful, the pans made of horn, and supported by threads to a brass beam. They should carry at least 10 ounces, and turn with one-half grain. The ore, litharge, test lead, oxidizing and reducing agents, should be weighed accurately. The ordinary fluxes may be weighed approximately; but it is better to weigh closely, as more uniform results are obtained. The gramme or decimal system of weights will be found most convenient in all cases, save perhaps in the assay of gold and silver ores, where a special system of weights, called the assay ton weights, will be found most convenient. The unit of the system is the assay ton = 29.166 grammes. Its derivation will be seen at a glance. 1 lb. avoirdupois = 7,000 troy grains. 2,000 lbs. = 1 ton. 2,000 × 7,000 = 14,000,000 troy grains, in 1 ton avoirdupois. 480 troy grains = 1 oz. troy. 14,000,000 ÷ 480 = 29,166 + troy oz. in 2,000 lbs. avoirdupois. There are 29,166 milligrammes in one assay ton (A. T.); hence, 2,000 lbs. is to 1 A. T. as 1 oz. troy is to 1 milligramme.

257.



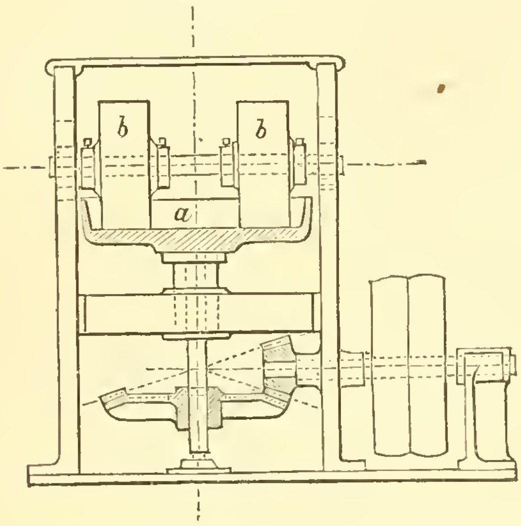

Example.—Weigh an A. T. of ore, and if on assay it yields one milligramme of gold or silver, the result reads 1 oz. troy in 2,000 lbs. avoirdupois, without further calculation.

The ore to be weighed out is spread upon glazed paper and mixed with a bone or steel spatula, and then sampled by taking a little from each part of the pile, until a sufficient quantity has been transferred to the scale-pan for the assay.

3. *Calcination and Roasting.*—If the ore be damp, it must be calcined to dry it, and then weighed

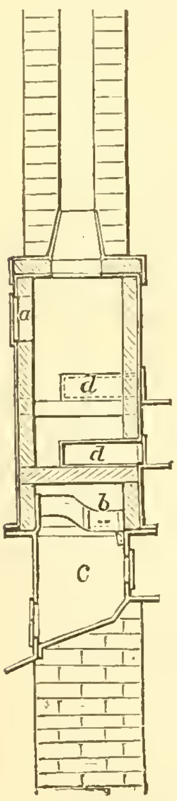
again; or if it be a sulphide, it must be roasted before charged in the crucible with the fluxes, etc. In calcination the object is simply to drive off moisture, while in roasting the operation is conducted in such a manner as to insure oxidation, and the elimination of sulphur, arsenic, antimony, etc. To calcine a substance, it is not necessary that the air should have free access, or that the material treated be stirred. For roasting, combustion must take place, and consequently the vessels employed must be open and flat to allow the oxygen of the air to act freely. The ore must be stirred continually, and when easily fusible be mixed with some substance to prevent agglutination. Charcoal, graphite, or sand may be used for this purpose. The heat should be low at first. Fig. 250 represents two sections of a convenient furnace for calcining or roasting. The fire-place is made shallow; and, as a high temperature is not required, it may be made of red brick, or only lined with fire-brick, and the body of the furnace bound with strap-iron. It should also have a cast-iron top-plate. The grate-bars may be in one piece or separate, and draw out. The ash-pit should be provided with a door, which may be closed or opened in order to regulate the draft. A hood of sheet-iron will also be found necessary in many cases, as the fumes given off in roasting are often injurious. It is an excellent plan to have the hood of galvanized iron to prevent rusting. The chimney may be of brick, iron, or clay.

258.

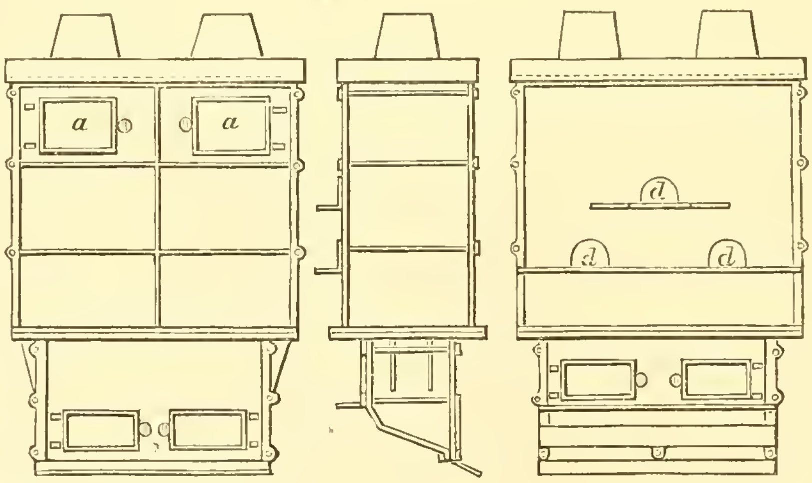



4. *Reduction and Fusion.*—In this operation the ore is heated with fluxes and reducing agents in a crucible or scorifier. Among the furnaces best adapted for this are those shown in Figs. 251 and 257. Fig. 251 shows a crucible furnace for fusion with inclined cover, to facilitate the lifting in and out of crucibles. Sometimes a crane is added for this purpose. The chimney ought to be of brick, and the larger and higher it is, the stronger the draft. This may be regulated by a damper as well as by the ash-pit door. The top should be of cast-iron, and the cover roll or slide easily. Fig. 252 shows a good form of tongs for lifting crucibles out of the furnace. They should be made with long handles, and bent as shown in the illustration.

5. *Scorification and Cupellation.*—Both of these operations may be classed as a combination of fusion, roasting, and sublimation, the difference being that in the latter case (cupellation) the volatile compounds formed are absorbed by the cupel, while in the former they form a slag. Fig. 253 shows




259.

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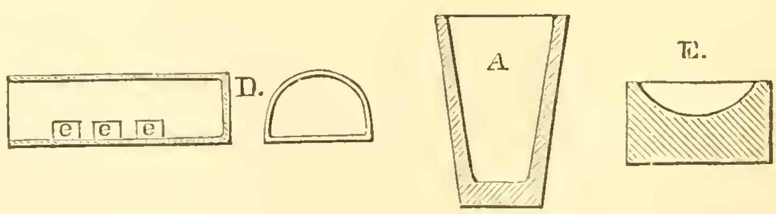



sections of a portable muffle furnace for scorification and cupellation. The same furnace may be used for both operations, but generally it will be found convenient to have a larger muffle for scorification and higher heat. The muffles are made of refractory clay, and in one piece, and should be thoroughly dried before using. Figs. 254 and 255 show the best forms of tongs for this furnace. In the scorification tongs, Fig. 254, the spring should not be too strong, and the horse-shoe part should just fit the scorifier. The cupel tongs, Fig. 255, should be made of steel, and be about $2\frac{1}{2}$ feet long,

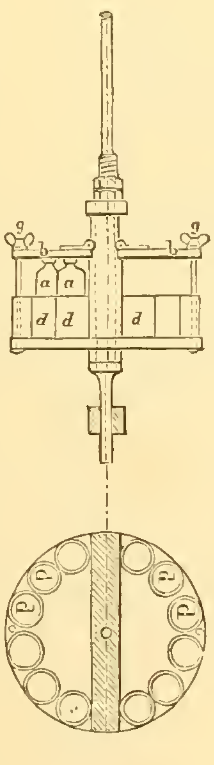
with an easy spring. Ores rich enough to be scorified do not require to be roasted, but may be assayed directly; so that this method is preferable to the crucible assay, as it saves time. For details of cupellation, see section II. of this article.

6. *Inquartation and Parting.*—Under this head come the separation of alloys and the treatment of the buttons from the gold and silver assay. Inquartation is the process of alloying gold with silver to form a more soluble alloy, while parting is the separation of the metals by solvents. Fig. 256 shows the glass vessel used for parting alloys of gold on a small scale. For a description of the apparatus used where a quantity of bullion is to be parted, see section II. The weighing of beads and bullion must be conducted with the greatest care, and the balance adjusted both before and after weighing. Before weighing, the bead or bullion should be well cleaned with a small brush.

II. Treatment of Alloys.*—The following is the method of parting, melting, and refining employed in the United States mints. All deposits of bars and gold-dust received at the mint are remelted in the crucible of a smelting furnace, shown in section at *a*, Fig. 257. *g* is the grate, *f* the fuel, *d* the ash-pit, and *e* the flue. To toughen impure brittle deposits, borax is added, which combines with the impurities, and on pouring appears on the surface of the bar as a slag, which is removed and ground in a small Chili mill, shown in Fig. 258. *a* is the revolving pan; *b b* are the rollers, 17 inches diameter by 6½ inches face. The pulverized slag is pan-washed, and any metallic result is added to the bar. From the remelted gold bars chips are taken off of two diagonal corners for assaying. For silver assays a small amount of metal is granulated by pouring it in water before and after casting, a little being left in the crucible for this purpose. After every operation performed on the metals, as well in melting and refining as in coining, they are weighed to determine the amount of loss by vaporization or abrasion.

The method of gold assaying at the mint is the dry or cupelling process. The cupel furnace used, shown in Fig. 259 in different views, is made of cast-iron, lined with 2 inches of fire-brick, and measures 11 by 30 inches in the clear, and 30 inches above the grate-bars. The fuel is charged at *a a*. *b* is the grate-bar, *c* the ash-pit, *d* the muffle (shown enlarged at *D*, Fig. 260). The gold is mixed with three times its weight of silver and about 11 parts of lead, and placed on a cupel *E*, in the muffle *D*, Fig. 260. The lead forms with the impurities a slag which is absorbed by the bone-ash cupel, the gold and silver alloy remaining in the shape of a button on cooling. The "button" is then flattened on an anvil, rolled into a strip, and finally bent into a spiral or S shape called a "cornet;" this is placed in a vial (matrass), and the silver dissolved out by nitric acid. The resulting pure gold is washed, dried in a porous crucible (shown at *A*, Fig. 260), and weighed. The weight before and after assaying gives the proportionate amount of gold in the piece. About 30 pieces from one deposit are thus assayed at the same time, and the mean result taken as correct.

261.

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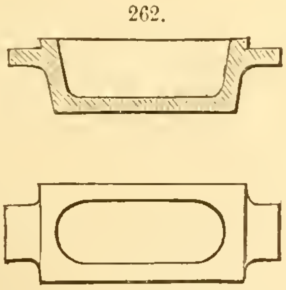

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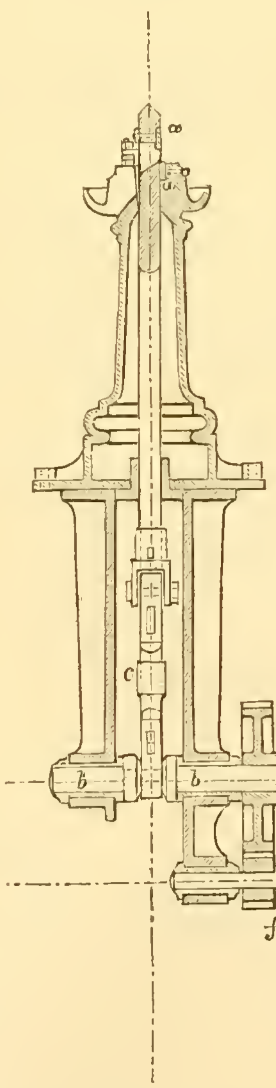
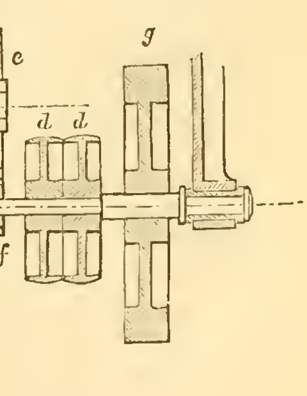
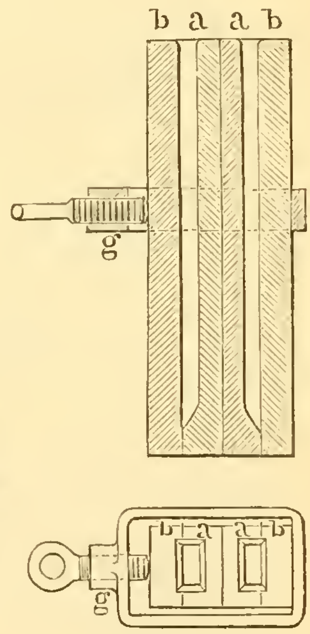




263.

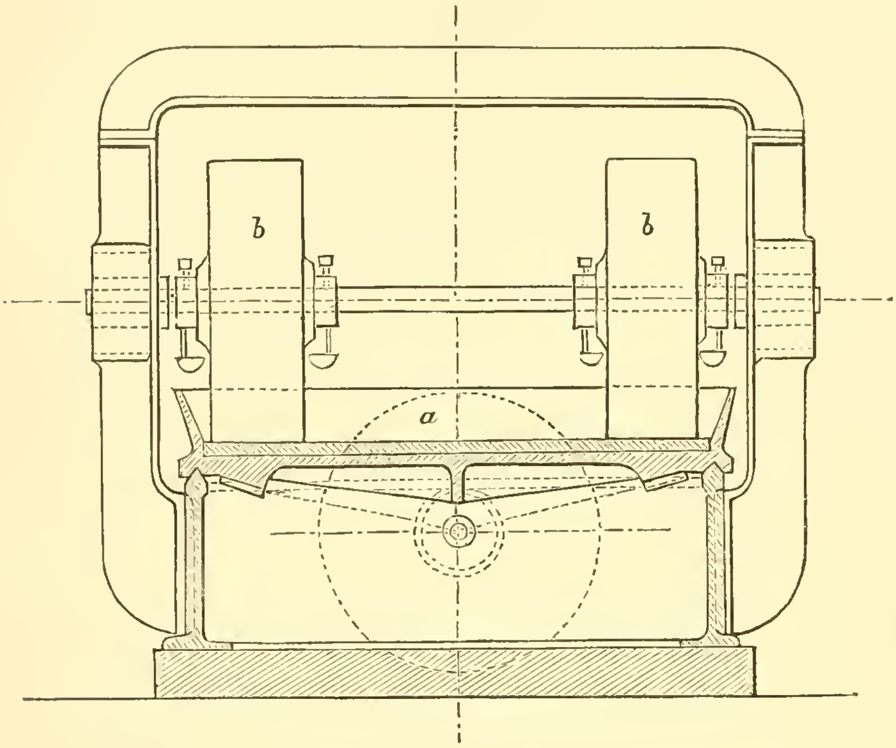



The humid assay is nearly always used for silver. Ten or more small pieces are placed in as many vials, and dissolved by nitric acid; after which the vials *a a* are set in the recesses *d d d* of the agitator shown in Fig. 261, and a standard solution of sea-salt added. The vials are then corked, and the covers *b b* fastened down by the screws *g g*. The agitator next receives, either by hand or machinery, a rapid vertical shaking motion, whereby the chlorine of the salt decomposes the nitrate of

* Contributed by Irving M. Scott.

silver, and chloride of silver falls as a white precipitate. The quantity of the salt solution required to precipitate all the silver from its nitrate determines the amount of silver in the vial. The precipitation is considered complete when no more of a cloudy stratum can be detected over the liquid. The weight of silver precipitated, compared to the weight before assaying, gives the proportionate amount in the piece, the mean of which is taken from all the assays.

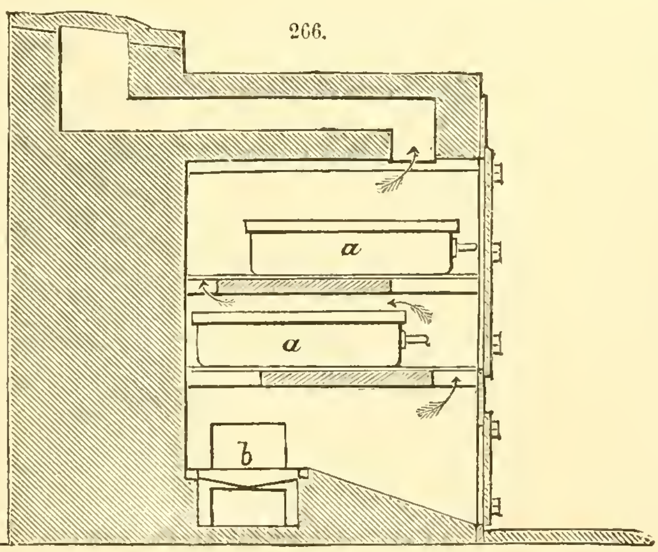
265.




*Refining.* — The assayed gold and silver deposits are melted together in the proportion of one gold and two silver, then granulated, and sent to the refinery department, where the mixture is treated with nitric acid in porcelain pots. The resulting silver solution is decanted from the unaltered gold into large vats, and by adding a solution of sea-salt chloride of silver is formed, which is separated from the liquor by filtration. The silver is then precipitated from the chlorine with zinc and sulphuric acid as a grayish-black powder, which is dried, pressed, and sent to the melting-room, where it is fused with borax and poured into cast-iron moulds, Fig. 262. The gold left in the pots is repeatedly treated with nitric acid, to remove all traces of silver, washed, pressed, and cast into bars of the size and shape of the moulds.

*Ingot-Melting.*—The refined metals are melted together with 100 parts of copper in 1,000, and cast into ingot-moulds. These moulds, Fig. 263, consist of four cast-iron plates, two of which, *a a*, have the shape of the mould cut out, the others, *b b*, acting as covers. The plates are held together by the dog *g*. Immediately after casting, the ingots solidify, and are removed from the moulds by unscrewing the dog, and dropped into cold water. Assays are made of the first and last ingot of each melt, and, if found to disagree sensibly with each other or the Government standard, the whole lot must be again melted and cast. The tops of the ingots, being rough and uneven, are cut off by the shears, *a a*, of a topping machine, Fig. 264, in which *b* is the crank-shaft, *c* the connecting-rod, *e* the gear and pinion, *d d* the pulleys, and *g* the fly-wheel.

266.




*Treatment of Sweeps.*—The slags, worn-out crucibles, and sweepings of the flues are sent to the sweep-room, where they are pulverized in a large Chili mill, Fig. 265, in which *a* is the revolving pan, and *b b* are rollers of 36 inches diameter and 12 inches face. The pulp from the mill passes through a bolting-screen, which separates any integral metallic parts, and thence into an amalgamator, where from 500 to 1,000 ounces of amalgam are collected per month. The amalgamator tailings are run into settling-tanks, thence shoveled into wrought-iron pans, and dried in a sweep-furnace, Fig. 266, where *a a* are the pans, and *b* is the grate. After about three hours' drying the pulp is packed into barrels, then concentrated and reworked as often as it will pay.

*Works for Reference.*—In the preceding pages the details of the processes for assaying many ores and alloys have been necessarily omitted; but the reader can obtain these by reference to the following works: "Sulphurets, Treatment," etc., Barstow, San Francisco, 1867; "Anleitung zur Berg- und Hüttenmännischen Probirkunst," Th. Bodemann and Bruno Kerl, Clausthal, 1857; "Treatise on the Assaying of Lead, Copper, Silver, Gold, and Mercury," Th. Bodemann and Bruno Kerl (translated by W. A. Goodyear), New York, 1865; "On Gold, Silver, and Iron," T. M. Blossom, *American Chemist* for 1870; "Practical Miners' Guide," J. Budge, London, 1866; "Assay of Gold and Silver Wares," A. Byland; "Metallurgische Probirkunst," Bruno Kerl, Leipsic, 1866; "A Practical Treatise

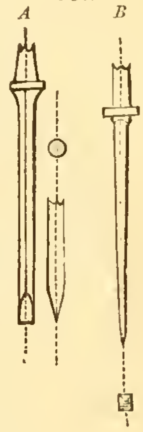
on Metallurgy," Wilhelm Kerl (edited by William Crooks and Ernst Rohrig); "The Assayers' Guide," O. M. Lieber; "Manual of Practical Assaying," John Mitchell (edited by William Crooks), New York, 1872; "Manual of Practical Assaying," John Mitchell, London, 1868; "Practical Assayer," Oliver North, London, 1874; "Practical Mineralogy, Assaying, and Mining," Frederick Overman, Philadelphia, 1863; "Notes on Assaying and Assay Schemes," Ricketts, New York, 1878; "Hand-Book for Miners, Metallurgists, and Assayers," Julius Silversmith; "Chemical Technology," F. Knapp; "Dictionary of Chemistry," Henry Watt, London, 1866–'72; "The Mints and Assay Offices of Europe," Ricketts; *Transactions of the American Institute of Mining Engineers*, vol. iv. Besides the above, almost all works on the chemistry of the metals treat more or less of the assay of the same. See also the annual reports of the directors of English and United States mints, which contain much valuable information. P. DE P. R.

ASTYLLEN. A small dam in an adit or mine, to check the passage of water.

AUGER. See BITS AND AUGERS.

AWL. A pointed instrument for piercing small holes, as in leather or wood. The *brad-awl*, *A*, Fig. 267, is the smallest boring tool. Its handle is the frustum of a cone tapering downward. The steel part is also conical, but tapering upward; and the cutting edge is the meeting of two basils, ground equally from each side. A hole is made by placing the edge transverse to the fibres of the wood, and pushing the brad-awl into the material, turning it to and fro by a reciprocatory motion. The core is not brought out as by other boring instruments, but the wood is displaced and condensed around the hole. The *wire-worker's awl*, *B*, Fig. 267, is less disposed to split the wood. It is square and sharp on all four edges, and tapers off very gradually until near the point, where the sides meet rather more abruptly.

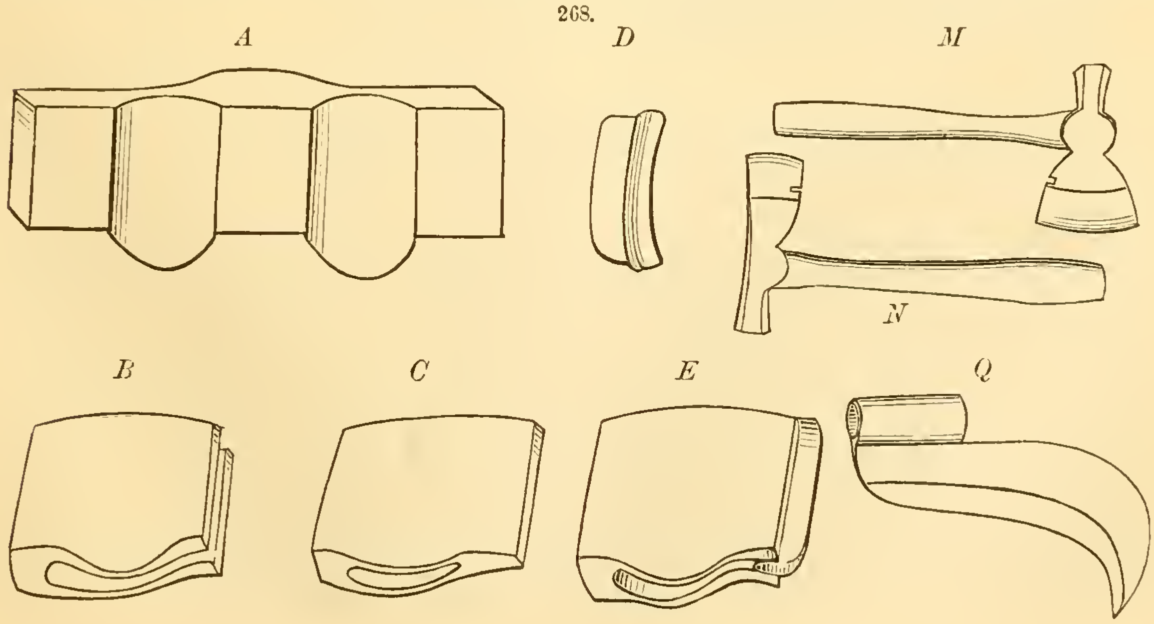
267.



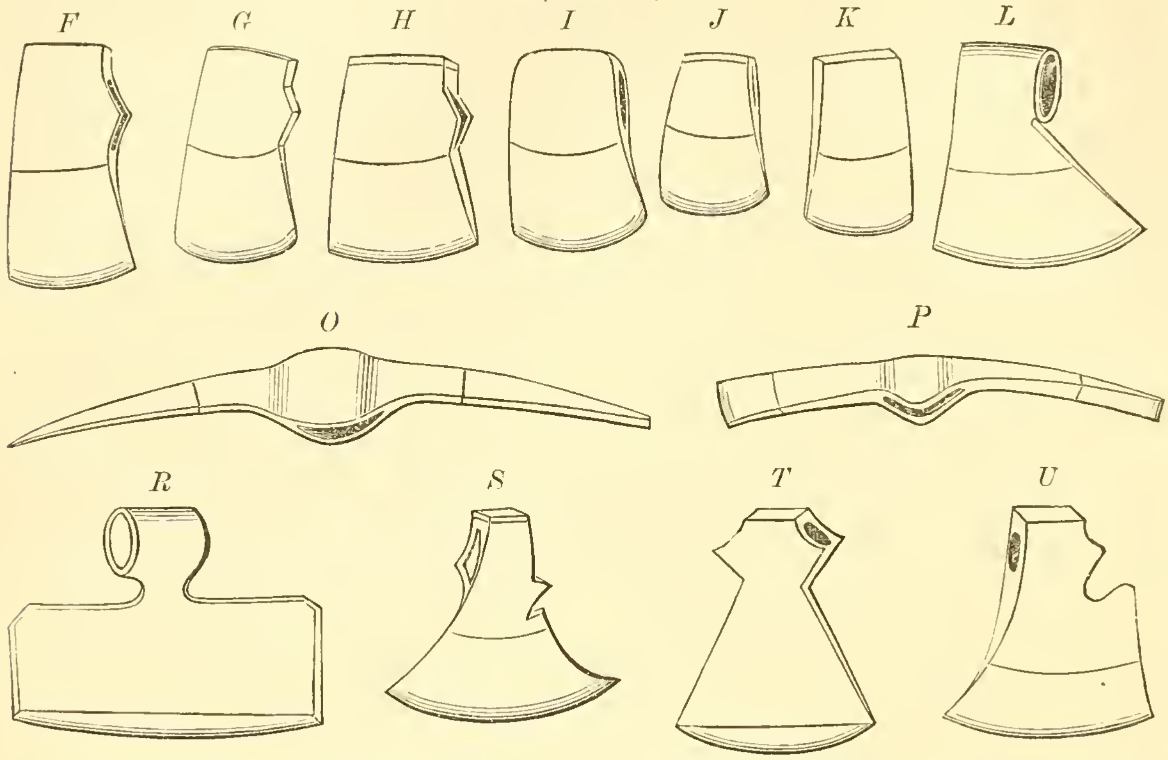

AXE. A cutting tool, usually of iron with a steel edge, used for hewing and chopping wood. The butt of the tool is made from a good quality of rolled iron, the bars of which are first cut into pieces of suitable length by heavy shears. The blanks are then passed through rolls, and thus made to assume the form shown at *A*, Fig. 268. By a simple machine the ends of the blank are brought together, or rather the blank is folded so as to assume the form shown at *B*, Fig. 268, the indentations on the side coming together roughly to form the eye. The blank in this shape is heated in an open furnace to a welding heat, and then, being placed under a trip-hammer, is forged to an approximation of its final form. The separated ends are welded together, and the eye is opened out, as shown at *C*. Meanwhile the steel edges or blades are being formed in the shape represented at *D*. The part which is to form the keen edge is left thick, as shown at *E*, while the portion to be inserted in the iron blank is made much thinner. The head or butt of the axe being again heated, the portion to receive the steel edge is split by means of a hand-wedge. Borax is introduced as a flux, and the edge is inserted, as shown at *E*. The tool is then brought to a welding heat, and the weld of steel and iron is made under a heavy trip-hammer. The form is finally shaped and trued by hand-hammers. In the tempering process which follows, the axes are heated to a low cherry-red and hardened in brine, the water being fully saturated with salt. The temper is subsequently drawn to a pigeon-blue. The remaining operations are grinding on large stones some 4 feet in diameter, polishing on emery-wheels, painting, and affixing the handle. The method of testing axes at the factory of the Weed & Becker Manufacturing Company, of Cohoes, N. Y., is simply to place several selected at random from a given number in the hands of an experienced axeman, and to allow him to prove their cutting power on a tough and knotty hemlock stump.

The shapes of axes depend in some degree upon the kind of timber on which the tools are to be used; but generally woodmen in various sections of the United States and in different parts of the world have special predilections for particular forms, the reasons for such preference being merely fanciful. From *F* to *K* are various forms of axes used in the United States. *F* is the Kentucky axe, weight from 3 to 7 lbs.; *G* is the Georgia long-bit axe, same weight; *H* is the New Jersey axe,

268.



268 (*continued*).



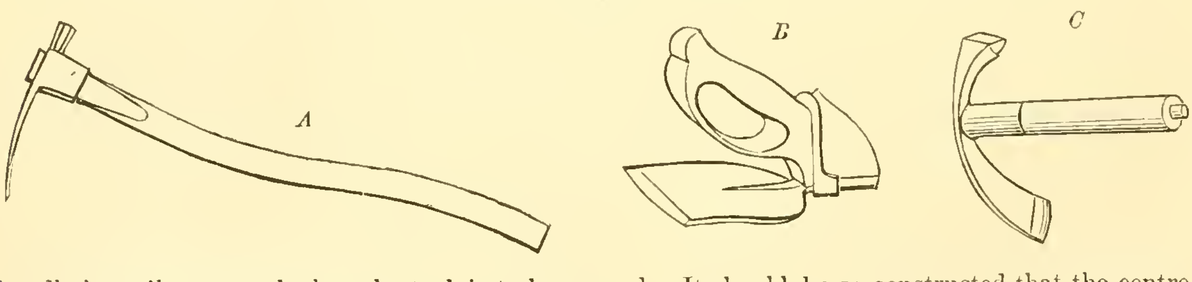

weight from 3 to 5½ lbs.; *I* is the Michigan or wide-bit axe, same weight; *J* is the Western axe, weight from 3 to 6 lbs.; *K* is the Yankee heavy-head axe, same weight. *L* represents the heaviest form of Spanish axe, the cut being from 8 to 8½ inches. *M* is a shingling hatchet or light hand-axe, and *N* is a lath hatchet.

Pickaxes are made in the manner above described for ordinary axes, the difference in manipulation being in the forging. *O* represents a mining pick, weighing from 3½ to 6 lbs. *P* is a light mattock; *Q*, a bush-hook for cutting underbrush and shrubbery; *R*, a cooper's axe; *S*, a Dutch side-axe; *T*, a broad-axe; and *U*, a coachmaker's axe.

All axes should be so constructed that either the centre of percussion or centre of gravity of the moving mass may be directly over and in the plane of the cutting edge. When the edge is required to throw chips, the plane passing through the centre of percussion must also pass through the bevel, and not through the cutting edge of the blade.

The adze is a hand-tool used by carpenters for chipping. It is formed with a thin arching blade, and has its edge at right angles to the handle. The edge is beveled only on the inside, and the

269.




handle is easily removed when the tool is to be ground. It should be so constructed that the centre of gyration of the moving mass is in the cutting edge. In Fig. 269, *A* represents the ordinary form of carpenter's adze; *B* is a small hand-adze; and *C* is the cooper's adze.

AXLES. See RAILWAY CARS.

BABBITT METAL. See ALLOYS.

BAC. 1. A scow or broad-beamed flat-boat, used for ferriage, usually navigated by a rope fastened on each side of the stream. 2. A cistern with a perforated metallic bottom, used for straining the hops from the beer previous to its entrance into the cooler.

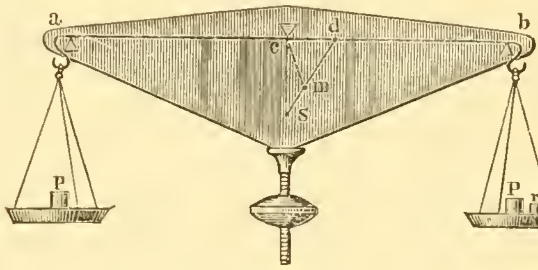
BACK-LASH. The jar which arises when a part of the machinery which ought to receive motion from another part suddenly falls back upon its driver. It is caused by wear or imperfect fitting.

BADIGEON. A cement for filling holes or covering defects in work. *Sculptors'*—Plaster and freestone. *Joiners'*—Sawdust and glue; whiting and glue; putty. *Coopers'*—Tallow and chalk. *Stone-Masons'*—Wood-dust and lime slaked together, with stone-powder or sienna for color, and mixed with alum-water to the consistence of paint.

BALANCE. An instrument intended to measure different amounts or masses of matter by the determination of their weight, using as standards of comparison certain fixed units, as the gramme, the pound, the ton, etc. The instrument is founded on the law that gravitation acts in a direct ratio to the mass, and on the mechanical principle that when a solid body is suspended on one point, the centre of gravity will place itself always perpendicularly under that point. If therefore a beam,

$a\ b$, Fig. 270, is supported in the middle at $c$, and movable around this point, its centre of gravity, $s$, will place itself under the point $c$; and if disturbed from that position, this centre will oscillate like a pendulum, and the beam will finally come to rest only with the centre of gravity in the perpendicular passing through the point of support. It is evident that when the distances from $a$ to $c$ and from $b$ to $c$ are equal, the two sides of the beam equal, and the whole made of homogeneous material, the horizontal position will be arrived at, and also when at $a$ and $b$ equal weights $p\ p$ are suspended. The gravity of such scales and weights must be considered concentrated in the points of suspension $a$ and $b$, and their common centre of gravity will be either in, under, or above the point of support, according as the line $a\ b$ uniting them passes through, under, or above the support $c$. But suppose we place an additional weight $r$ in one of the scales, then the common centre of gravity of the weights in the scales will be shifted toward the side of that additional weight. Suppose it to be in $d$, then the centre of gravity of the whole balance will be in the line $d\ s$, uniting the centre of gravity $d$ of the weights with that of the balance $s$; if then it is somewhere at $m$, it is evident that the balance can no longer maintain the horizontal position, but will only come to rest when $m$ is under $c$, or the line $c\ m$ has attained a perpendicular position. It is evident that the angle which the beam in this case makes with a horizontal line is equal to the angle $s\ c\ m$. If the centre of gravity is in the point of support, the balance is indifferent; that is, it will, when charged with equal weights, remain at rest in any position. And if the centre of gravity is above the point of support, we have a case of so-called unstable equilibrium; the balance will with equal ease tip over to the right or left, and the beam can never be brought into the horizontal position. In either case the balance is useless, and it follows from this that the centre of gravity must be under the point of support, and the sensitiveness of the instrument depends to a great extent on the distance between these two points. This derived degree of sensitiveness varies with the purposes for which balances are to be used.

270.




The most delicate balances are those used for physical and chemical investigation; and in order to secure the greatest possible degree of sensitiveness the conditions are as follows: 1. The centre of gravity of the beam must lie as near as possible under the point of suspension; it is evident that when this centre of gravity $s$ is raised, the point $m$ will be raised also, and the angle $s\ c\ m$ will become larger, which results in a greater deflection of the beam in case there is no proper equilibrium. Fine balances are provided with an upright rod above their point of suspension, on which a small weight may be screwed up or down, in order to raise or lower the centre of gravity, and so to increase or diminish the delicacy of the instrument. In Fig. 270 this rod is represented below, which is only admissible when no great degree of sensitiveness is required, as in this case the centre of gravity is lowered too much. 2. The beam should be as long as compatible with strength. As the distance $c\ d$ becomes greater in proportion to the length of the arms, any difference in the two weights with which the balance is charged will be the more perceptible the longer the arms are. 3. The beam should also be as light as compatible with strength; the smaller the weight of the balance itself, the greater the influence of minute differences in the load will be to shift the position of the point $d$ from the centre. Therefore the beams of chemical balances are made like an elongated frame, with large openings between, on the same principle as the walking-beams of steam-engines are constructed. 4. The points of suspension of the two scales must be such that the line uniting them passes exactly through the point of support; if this line passes under that point, the sensitiveness of the balance will diminish too much when the load is increased. This takes place in any case to a small degree, as no beam is so perfectly inelastic that a slight flexion will not take place under the maximum load. 5. The distances of the points of suspension of the scales $a$ and $b$ from the centre $c$ should be perfectly equal; this is best verified by changing the weights in the two scales, when, if the equilibrium remains unchanged, their distances are equal. Some balances have screw arrangements to correct small differences in this respect.

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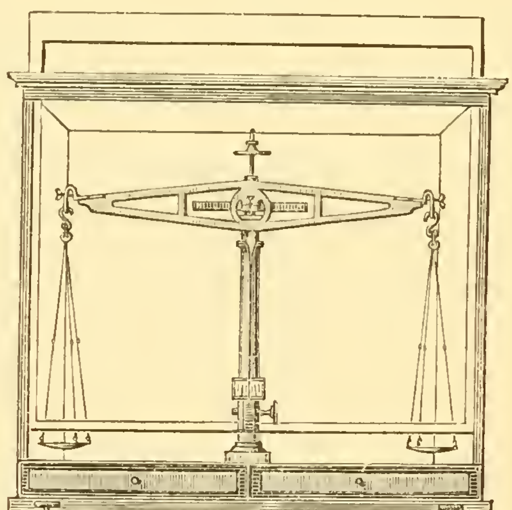


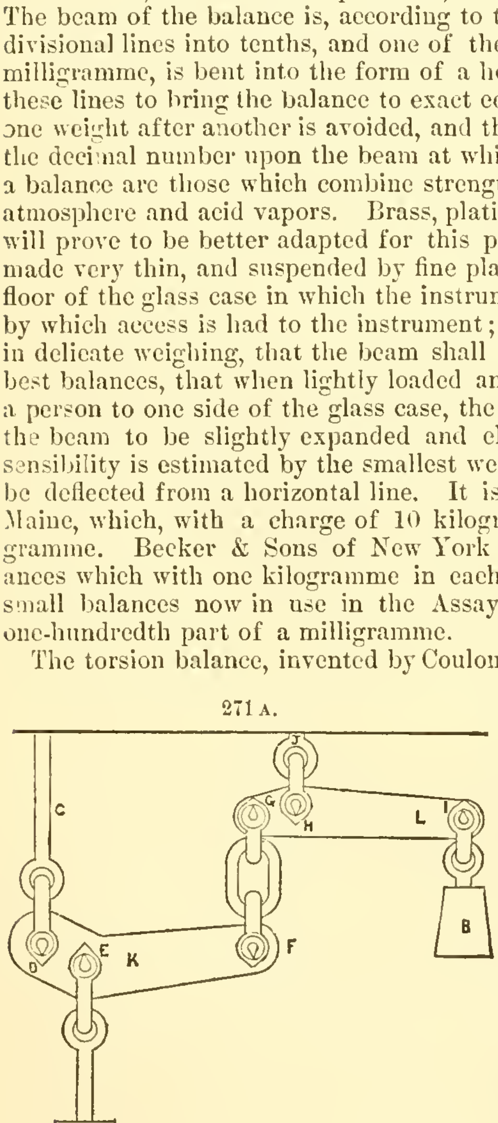
In Fig. 271 a chemical balance is represented as used, in a glass case, which serves to protect it not only from dust, but also against air-currents, which might prevent a truly sensitive balance from ever coming to rest, and thus make correct weighings impossible. The turning-point of the beam, in order to reduce the friction to the least amount, is a knife-edge or triangular prism of hardened steel passing at right angles through the beam, and resting when in use upon polished plates of agate (one each side of the beam), which are set exactly upon the same horizontal plane. This knife-edge is polished, and brought to an angle of 30°. The points of suspension are also knife-edges, one set across each extremity of the beam. Great care is required that the line connecting them shall be

precisely at right angles with the line passing through the centres of motion and of gravity. The index or pointer is sometimes a long needle, its line passing through the centre, and extending either above or below the beam, or it is a needle extended from each extremity of the beam. In either case it vibrates with the motion of the beam over a graduated arc, and rests upon the zero point when the beam is horizontal. The degrees upon each side of the zero of the scale indicate, as the needle oscillates past them, the intermediate point at which this will stop, thus rendering it unnecessary to wait its coming to rest. In order to save the knife-edges from wear, the beam is made, in delicate balances, to rest when not in use upon a forked arm, and the pans upon the floor of the case in which the instrument stands. The agate surfaces, being lifted by means of a cam or lever, raise the beam off its supports and put it in action; or the supports, by a similar contrivance, are let down from the beam, leaving it to rest upon the agate; the pans in the latter case must always remain suspended.

However perfectly a balance may be made, there is always great care to be exercised in its use. Errors are easily made in the estimation of the nice quantities it is used to determine. The sources of some are avoided by a simple and ingenious method of weighing suggested by Borda. The body to be weighed is exactly counterpoised, and then taken out of the pan and replaced by known weights, added till they produce the same effect. A false balance must by this method produce correct results. The weights employed for delicate balances are either troy grains, one of each of the units, one of each of the tens, and the same of the hundreds and thousands, as also of the tenths, hundredths, and thousandths of a grain; or they are the French gramme weights, with their decimal parts. The latter are the most commonly used in chemical assays and analyses. The larger weights are of brass, the smaller of platinum, and these are always handled by means of a pair of forceps. The beam of the balance is, according to the method introduced by Berzelius, frequently marked by divisional lines into tenths, and one of the small weights, as a tenth or hundredth of a grain, or a milligramme, is bent into the form of a hook, so that it may be moved along the beam to any one of these lines to bring the balance to exact equilibrium. By this arrangement the picking up and trying one weight after another is avoided, and the proportional part of the weight used is that indicated by the decimal number upon the beam at which it rests to produce equilibrium. The best materials for a balance are those which combine strength with lightness, and are least liable to be affected by the atmosphere and acid vapors. Brass, platinum, or steel is used for the beam; but probably aluminum will prove to be better adapted for this purpose than either. The pans are commonly of platinum, made very thin, and suspended by fine platinum wires. The support is a brass pillar secured to the floor of the glass case in which the instrument is kept. Doors are provided in front and at the sides, by which access is had to the instrument; but these are commonly kept closed, and are always shut in delicate weighing, that the beam shall not be disturbed by currents of air. So delicate are the best balances, that when lightly loaded and left to vibrate, they may be affected by the approach of a person to one side of the glass case, the warmth radiated from the body causing the nearest arm of the beam to be slightly expanded and elongated, so as to sensibly preponderate. The degree of sensibility is estimated by the smallest weight in proportion to the load that will cause the beam to be deflected from a horizontal line. It is said that a balance is in possession of Bowdoin College, Maine, which, with a charge of 10 kilogrammes in each scale, is sensitive to one-tenth of a milligramme. Becker & Sons of New York made the balance; and they make ordinary chemical balances which with one kilogramme in each scale are sensitive to one-tenth of a milligramme; their small balances now in use in the Assay Office, New York, show a difference in load of less than one-hundredth part of a milligramme.

The torsion balance, invented by Coulomb to measure minute electrical forces, is still more delicate than the best beam balance. It consists of a brass wire, hung by one end and stretched by a light weight, carrying at its lower end a horizontal needle. Any force applied to one end of this needle, tending to rotate it horizontally, will be measured by the angle through which it causes the needle to move; that is, by the torsion of the wire.

271 A.




The steelyard, the Roman *statera*, is one of the forms of the balance, the two arms being of unequal length, the body to be weighed being suspended in a pan or otherwise from the short arm, and the counterpoise, which is a constant weight, being slid along the longer arm until equilibrium is established. As this occurs when the weight on one side multiplied by its distance from the fulcrum is equal to the weight on the other multiplied by its distance from the fulcrum, and as on one side the weight is constant, and on the other the distance from the centre of motion is variable, the unknown weight must be determined by the distance of the constant weight from the centre. The Danish balance differs from the common steelyard in having the counterpoise fixed at one end, and the fulcrum being slid along the graduated beam. The graduation commences at a point near the counterpoise, at which the beam with the pan suspended at the other end is in equilibrium, and the numbers increase toward the pan. A balance called the bent lever is employed to some extent for purposes not requiring extreme accuracy. The pan is attached to one end of the beam, and the other carries a constant weight. From the bent form of the lever this weight is raised to a height varying with the weight placed in the scale pan. A pointer attached to the constant weight and moving along a grad-

uated arc indicates by the number at which it stops the weight of the body in the scale-pan. Its indications are the least to be depended upon when the constant weight approaches to the horizontal or vertical line passing through the centre of motion. The scales generally used in the United States for weighing loaded wagons and canal-boats are modifications of the steelyard, wherein the weight of these ponderous bodies is divided by means of levers, and a known fraction of it sustained by one end of a beam, the other end of which is graduated for a moving weight. Modern modifications of the steelyard contain a pan hung at the end of the arm to receive larger weights, while the sliding weight is used only to balance the fractional parts.

The principle of platform scales, or weighing machines, is nearly if not quite the same in all scales and balances. But the same principle is carried out in different forms. The old style of balance was only an even beam. The new style is a multiplying beam, or in most cases a set of multiplying beams or levers. It will be seen from Fig. 271 A that when the lever *K* is suspended by the rod *C*, the weight and lever resting on knife-edges *D* and *F*, by applying a certain weight to *E*, as shown at *A*, it will pull down a certain amount at *F*, according to the difference between *E* and *D* and *E* and *F*. The weight being reduced at *F*, it is transferred to the second lever *L* at *G*. *L* being suspended at *H* by the bolt *J*, the weight is again transmitted and reduced to *I*. In this way it may be reduced to almost any given amount; for instance, *A* may weigh 500 lbs., and just balance *B*, which only weighs 25 lbs.; or it may be reduced, as is the common practice in platform scales, so that 100 lbs. at *E* will just balance 1 lb. at *I*; or in larger scales, such as are used for weighing wagons, it is reduced to 1 lb. to 500, or 1 lb. at *B* when 500 lbs. are applied at *A*. This system of multiplying levers is used in all platform scales, the principal difference being in the pattern, material, and workmanship. Pipe and knee or right-angle levers are sometimes used in order to make the article cheaper; but they are also only multiplying levers.

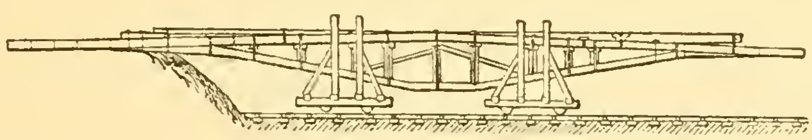
Spring balances are popular instruments, and consist of a helix of wire inclosed in a cylinder. The body to be weighed is suspended to a wire passing up through the centre of the helix and fastened to the upper coil, which carries a pointer down a narrow slit in the cylinder, thus indicating the weight on the graduated sides of the cylinder.

See Lever, under Statics. For assaying-balances, see Assaying. For balance-wheels, etc., in watches, see Watch and Clock Making. See also "Science of Weighing, Measuring, and Standards," Chisholm, 1877; "Chemical Manipulations," Faraday, for construction and management of delicate balances used in quantitative analyses. Illustrations of nearly all modern forms of balances and scales are contained in a pamphlet issued by Messrs. Fairbanks & Co. of New York.

BALANCE-RYND. In mills, the iron bar stretching across the eye of the runner, and by which it is poised on the top of the spindle.

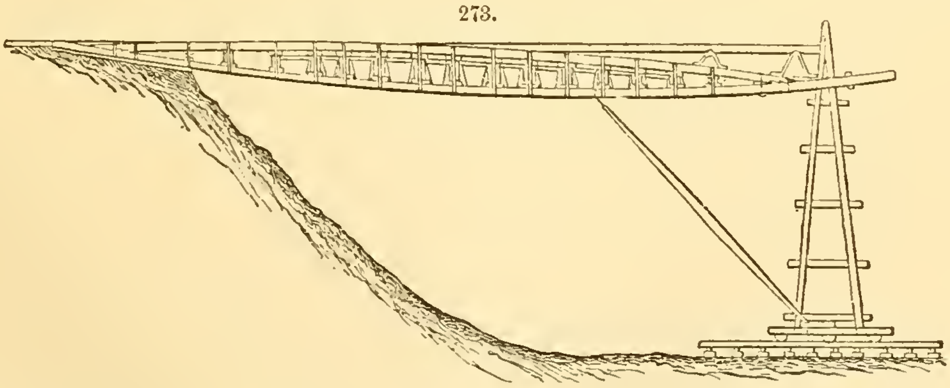
BALEINE. Figs. 272 and 273. A movable scaffold employed in France to facilitate the tipping of the wagons in railroad-embankments. It consists of two trussed beams, which are laid with rails along

272.



the top, one end resting on the ground at the battery-head of an embankment in course of formation; the other end of the baleine rests on a wheeled carriage or railway, the rails of which are taken up at

273.



one end as the other progresses. When a car is tipped at the battery-head, its contents are discharged between the rails, and it is pushed to the other end of the baleine.

BALIZE. A frame of timber for a beacon or landmark.

BALLOON. See Air-Ship.

BAND-SAW. See Saws.

BANKER. 1. In bricklaying, a bench used in dressing bricks to peculiar shapes. On one end of it is a grit-stone called a *rubbing-stone*, and on other portions is room for operating upon the bricks with the *tin saw*, by which *kerfs* are made in the bricks to the depth to which they are to be hewn. 2. In sculpture, a modeler's bench, supporting a platform which can be rotated to expose any side of the work.

BAPTATERIUM. A bark-mill, or fulling-mill.

BARI. The portion of a roofing-slate showing the gauge, and on which the water falls.

BAROMETER. An instrument used for observing the pressure and elasticity, or variations in density, of the atmosphere. It is commonly employed for the purpose of determining approaching variations in the weather, and more scientifically for measuring altitudes. There are various modifications of the barometer, as the diagonal, horizontal, marine, pendent, reduced, and wheel barometer; in all of which the principle of construction is the same, the only difference being in its application.

The essential part of a barometer is a well-formed glass tube, closed at one end, perfectly clear and free from flaws, 33 or 34 inches long, of equal bore, filled with pure mercury, and inverted, the open end being inserted in a cup partly filled with the same metal, so that the mercury in the tube may be supported by atmospheric pressure.

The vacant space between the top of the mercury and the top of the tube is called the Torricellian vacuum, in honor of the inventor of the instrument.

On pouring mercury into the barometer-tube and inverting it, the air thus confined between the mercury and the inner surface of the tube will escape into the Torricellian vacuum. In order to get rid of this air, as well as moisture, the tube is first gently warmed, so as to dry it thoroughly. A quantity of pure mercury is then poured in, so as to occupy 2 or 3 inches of the sealed end of the tube, which is held over the fire until the mercury boils, taking care to turn the tube round upon its axis, so that the heat may be equally applied. After boiling for a minute or two, the open end is closed by a cork to prevent the introduction of moist air, and the tube is then allowed to cool, in order that the cooled mercury which is next to be poured in may not crack the tube. When a second portion of mercury, about equal to the first, has been poured in, the part of the tube containing this new portion is held over the fire until it boils. It is again removed from the fire and corked up as before. A third portion of mercury is then introduced, and the heat again applied to that part of the tube containing the last addition of metal; and in this way the tube is at length filled, with the exception of a small portion from which the mercury has been expelled by the heat. This is filled up with mercury, and the finger is now placed over the opened end so as carefully to exclude any air; the tube is then reversed into a cup of pure mercury; as the column sinks, it expels the last portion of mercury which had not been boiled; and as there is neither air nor aqueous vapor above the mercurial column, its length exactly measures the atmospheric pressure. A film of air is always retained on the outside of the tube, and also at its under edges, which film creeps by small portions at a time into the interior, and rises up in innumerable bubbles into the vacuum, the film being constantly renewed by the descent of more air between the outside of the tube and the mercury in the cup, and thus the outer air slowly insinuates itself into the barometer. In this way the most carefully-constructed barometers have become deteriorated in the course of years.

This irregular and uncertain deterioration of barometers was remedied by Prof. Daniell, by uniting a ring of platinum with the open end of the barometer-tube, so as to bring it into contact with the mercury, thus effectually preventing the ingress of air into the tube.

The same philosopher also invented a new mode of filling barometer-tubes, by pouring the mercury into the tube while both are under the exhausted receiver of a good air-pump. The mercury is poured through a long slender funnel extending to the bottom of the tube, and dipping into a small portion of mercury previously introduced, and boiled. By this means all agitation is confined to the tube of the funnel, and the tube left perfectly free of air. The mercury was afterward boiled *in vacuo*.

The excellence of the barometer chiefly depends on the absence of all matter except mercury from the tube, and its value may be tested by three indications: 1. By the brightness of the mercurial column, and the absence of any flaw, speck, or dullness of surface; 2. By the *barometric light*, as it is called, or flashes of electric light in the Torricellian vacuum, produced by the friction of the mercury against the glass, when the column is made to oscillate through an inch or two in the dark; 3. By a peculiar clicking sound, produced when the mercury is made to strike the top of the tube. If air be present in the tube, it will form a cushion at the top, and prevent or greatly modify this click.

The sectional area of the tube is of no consequence; as the atmosphere presses with the same intensity upon the surface of the mercury in the cup, the column suspended in the tube will be of the same height, whatever its internal diameter.

The height of the mercurial column must be measured from the surface of the mercury in the cistern. When the atmospheric pressure increases and the mercury in the tube rises, a portion of the metal is drawn out of the cistern into the tube, and the level of the mercury in the cistern is depressed; so, on the contrary, when the atmospheric pressure diminishes, a quantity of mercury is forced out of the tube into the cistern, and the level of the metal in the latter rises.

In some instruments the scale, accurately divided into inches and parts of inches, is made movable, and terminates in an ivory point, which is brought down to the surface of the mercury. When this point and its reflection appear to be in contact, the height indicated by the scale is correct. In other forms of the barometer the mercury in the cistern is always maintained at the same level, for which purpose the cistern is formed partly of leather, so that, by means of a screw at the bottom, the surface of the mercury may always be adjusted to the neutral point before taking an observation. The divisions of the scale usually begin at the 27th inch, and are continued to the 31st. But in instruments intended to measure the height of mountains, or for accompanying balloons, the scale begins at the 12th or 15th inch. Each inch is divided into 10 parts, and these are subdivided into 100ths by means of a small sliding scale, called a *vernier* or *nonius*.

The barometer ought to be fixed in a truly vertical position, and, if possible, with a northern aspect, in order that it be subject to as few changes of temperature as possible. It is usual, for the sake of comparison, to reduce the observations to 32°, for which purpose tables for correction for temperature are given in scientific works devoted to the subject of the barometer. The height of the cistern of the barometer above the level of the sea, and, if possible, the difference of the height of the

mercury with some standard, should be ascertained, in order that the observations made with it should be comparative with others made in different parts of the country. Before taking an observation, the instrument should be gently tapped, to prevent any adhesion of the mercury to the tube; the gauge should be adjusted to the surface-line of the cistern, and the index of the vernier brought level with the top of the mercury.

Various contrivances have been made for increasing the length of the scale, or for making it more convenient for use. The most popular form is the common wheel-barometer, as it is called. In this instrument the tube, instead of terminating at the bottom in a cistern, is recurved, so as to form an inverted siphon. As a rise of the mercury in the longer or closed limb is equivalent to a fall in the shorter limb, and *vice versa*, a float is placed on the surface of the mercury in the shorter limb, and is connected with a string passing over a pulley, and very nearly balanced by another weight on the other side of the pulley. An index-hand attached to the pulley moves over the surface of a dial-plate, graduated so as to indicate the oscillations of the mercurial column. With an increase of atmospheric pressure the mercury in the longer tube rises, and that in the short tube is depressed, together with the float, and this gives a small motion of revolution to the pulley, and also to the attached index-hand. A fall in the longer column causes the mercury, with its float in the short limb, to rise, and consequently moves the index-hand in the contrary direction.

The *measurement of heights* was the first useful purpose to which the barometer was proposed to be applied.

Although the atmosphere may extend to the height of 45 miles, yet its *lower half* is so compressed as to occupy only $3\frac{1}{2}$ miles, so greatly do the upper portions expand when relieved from pressure.

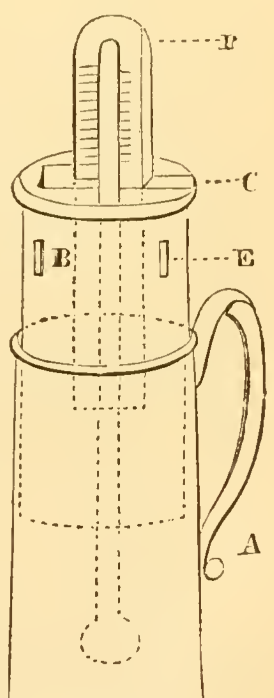
Hence, at the height of $3\frac{1}{2}$ miles, the elasticity of the atmosphere is one-half; at 7 miles, one-fourth; at $10\frac{1}{2}$ miles, one-eighth; at 14 miles, one-sixteenth, etc.

Halley was induced, by certain mathematical considerations, to fix upon the number 62,170 as a constant multiplier, and the rule for the measurement of heights may be stated as follows: Observe the height of the barometer at the earth's surface, and then at the top of the mountain, or other elevated station; take the logarithms of these numbers, and subtract the smaller from the greater; multiply the difference by 62,170, and the result is the height in English feet. This process gives a very near approximation, especially in temperate climates.

But the progress of science soon rendered it evident that a correction for temperature was necessary in barometrical measurements, and a formula has been contrived to meet most of the difficulties of the question. The following rule will be found of easy application: Multiply the difference of the logarithms of the two heights by the barometer by 63,946; the result is the elevation in English feet. Then, in order to correct for temperature, take the mean of the temperature at the two elevations. If that be 89.68° Fahr., no correction is necessary; if above that quantity, add $\frac{1}{480}$ to the whole height found for each degree above 69.68°; if below, subtract the same quantity. For example, Humboldt found that at the level of the sea, near the foot of Chimborazo, the barometer stood at exactly 30 inches, while at the summit of the mountain it was only 14.85. The logarithm of 30 is 1.4771213, and the logarithm of 14.85 is 1.1717237; then subtracting

$$\begin{array}{r} 1.4771213 \\ 1.1717237 \\ \hline 0.3053976 \end{array}$$

274.




multiply this by 63,946, which produces 19,539 for the elevation in feet. If the mean temperature of the two stations be 69.68°, no correction is necessary for temperature. This is a tolerably close approximation. The most careful calculation has given 19,332 for the real height, and this was probably estimated for a lower temperature.

A method has been given by Leslie for measuring heights without the use of logarithms. His rule is as follows: Note the exact barometric pressure at the base and the summit of the elevation, and then make the following proportion: As the sum of the two pressures is to their difference, so is the constant number 52,000 feet to the answer required in feet. Suppose, for example, the two pressures were 29.48 and 26.36; then

As 29.48 + 26.36 : 29.48 — 26.36 :: 52,000 feet : 2,905.4 feet, the answer required.

This rule has been found applicable to the mean temperature of England for all heights under 5,000 feet.

Another method of obtaining approximate differences of altitude is by a comparison of the *temperatures* of boiling water (which vary with the pressure of the atmosphere). The apparatus is exceedingly simple, and the instrument not so liable to injury as the mercurial barometer, being much more portable, and easily replaced. Fig. 274: *A*, common tin pot, 9 inches high by 2 in diameter. *B*, a sliding tube of tin, moved up and down in the pot; the head of the tube is closed, but has a slit in it, *C*, to admit of a thermometer passing through a collar of cork, which shuts up the slit when the thermometer is placed. *D*, thermometer, with so much of the scale as may be desirable. *E*, holes for the escape of steam.

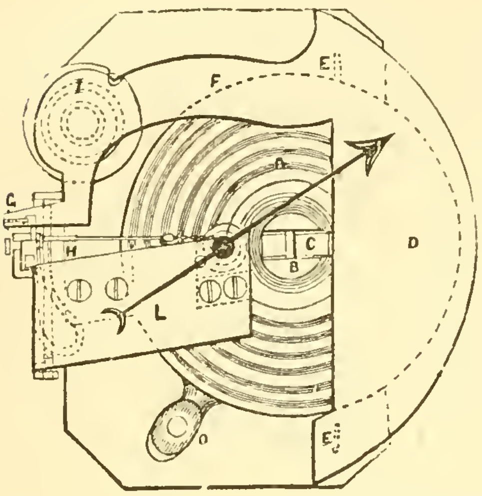
The boiling-point for the level of the sea should be correctly marked by a number of careful observations, and the difference, if any, must be noted as an index error.

These thermometers are very useful in ascertaining heights where strict accuracy is not required, and they have the advantage over mercurial barometers in being portable. In moderate elevations,

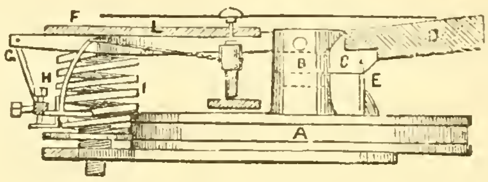
the difference of *one degree* in the temperature at which water boils indicates a change of level of *about* 500 *feet*, corresponding to a difference of 0.6 of an inch in a mercurial barometer.

*Aneroid Barometer.*—The action of the aneroid depends on the pressure of the atmosphere on a circular metallic box hermetically sealed, and having a slightly elastic top, the vacuum serving the purpose of the column of mercury in the ordinary barometer. The construction of the aneroid is illustrated in Figs. 275, 276, and 277. The vacuum-chamber is represented at *A*; its top and bottom

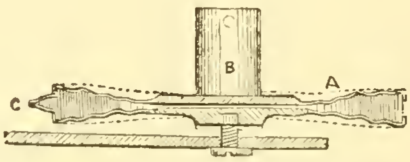
275.




276.




277.

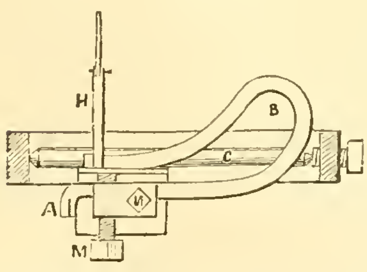



are formed of disks of thin circularly corrugated copper, held together by a circumferential strip of plain metal, as shown in the detail, Fig. 277, which is a vertical section of the chamber detached. A strong brass stud *B* is attached to the upper diaphragm of the chamber, having a slot on its end, through which a small projecting pin *C* formed on the lever-plate *A* projects, the attachment being effected by a pin passed transversely through the slotted portion of the stud, immediately over the pin *C*. The plate *D*, which acts as a lever in communicating the movements of the diaphragm, rests upon two pillars *E*, carried by the supporting base-plate of the vacuum-chamber as fulcra. The projecting lever-portion *F* conveys the movement by a joint at *G*, which is linked to a rocking-spindle carrying the lever *H*, connected to the arbor of the index-needle by a fine chain which winds upon it, like the mainspring chain of a watch upon the spring-box. In the interior of the vacuum-chamber a single helix is fixed upon the base-plate, so as to abut against the lower surface of the lever at *I*, and thus preserve the two diaphragms of the chamber from actual contact.

To set the instrument to indicate the same scale as the mercurial barometer, the arrangement given full-size in Fig. 278 is adopted, to form the connection between the main lever and the index-arbor. The link from the end of the main lever is joined to an eye at *A*, on a stud formed upon the end of a metal bow-piece *B*, the contrary end of which is attached to the lever *H*, before described. The whole of these parts are carried by a nicely-adjusted rocking-spindle *C*, working on centres in the frame *L*. The office of this contrivance is to afford a means of adjustment for the index-movement by the two screws *M N*, one of which elevates or depresses the eye *A*, while the other sets it in or out from the centre of the rocking-spindle, to give more or less leverage, as may be required to suit the barometrical scale. The connection between the index-arbor and the lever-apparatus being by a flexible chain, its movement can act only in one direction in bringing round the index, and a fine hair-spring is attached to give the return-movement.

The tube by which the exhaustion is effected is at *O*. The process of exhausting, as specified by the inventor in connection with the original plan, is as follows: A little solder is placed round the aperture for the exhaust, in which a flat-headed pin is set, so open as to admit the air to pass. The diaphragm is compressed to its proper position by means of a board, and is then soldered to its box. The whole is afterward placed under an air-pump receiver having an air-tight stuffing-box, through which a rod carrying the heated soldering-iron is passed. When the vacuum is obtained, the soldering-iron is pressed down, to melt the solder round the peg and close the opening.

278.




A simple mode of adjusting the instrument by a standard barometer is obtained by a screw-stud projecting through the back of the instrument, in connection with the reacting-spring at *I*, the tension of which may thus be varied to the extent required. By a simple arrangement, the vacuum-case is itself made to afford its own temperature-correction, without the addition of a particle of mechanism. Previous to the exhaustion of the vacuum-chamber, the top and bottom diaphragms are both perfectly horizontal; but when exhausted, they each take the curve shown in the section, Fig. 277, and the dotted lines represented as running nearly even with the corrugated surfaces indicate the position they will assume when a portion of gas is introduced to play the important part of a compensator for the disturbance to which the index would be liable from changes of temperature. The expansion of the contained gas, arising from the disturbing cause itself, counteracts the loss of elastic force produced by the same cause in the diaphragms and other parts of the machinery. The external atmosphere is continually endeavoring to press down the diaphragm, while the helix beneath the lever is

as continually acting to keep it up. An increase in temperature expands the contained gas, which thus diminishes the effect of the external atmospheric pressure, and corrects the disturbance arising from the expansion of the various levers and connections, which would otherwise indicate upon the dial a greater amount of movement than is actually due to the atmospheric change.

The following convenient rule for measuring altitudes by the aid of the aneroid barometer is from the "Hand-Book to South Africa:" Read the aneroid at $A$, say 30.15; take it to $B$, read it there, say 29.08; take it back to $A$, read it again, say 30.19. Then take the mean of the readings at $A$, and find the difference between that and the reading at $B$; multiply the difference in hundredths by 9, and the result will be the difference of altitude in feet—thus:

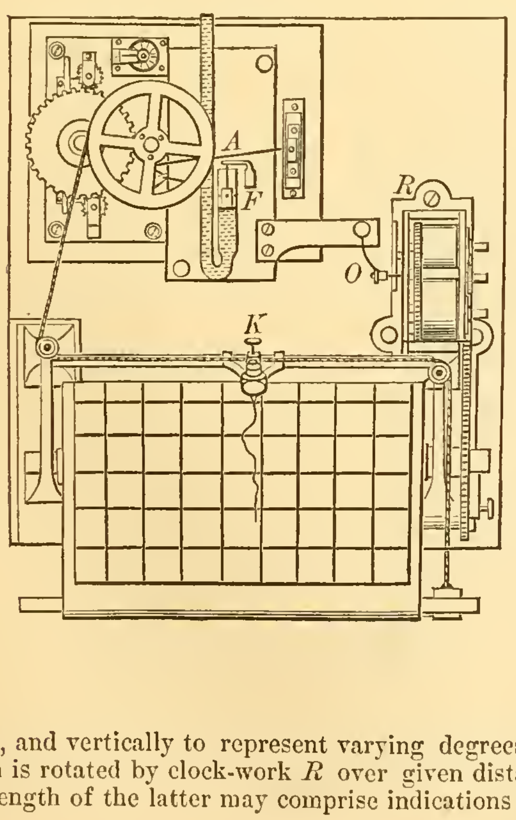
$$\frac{30.15 + 30.19}{2} = 30.17;\ 30.17 - 29.08 = 1.09;\ \text{then } 109 \times 9 = 981, \text{ height in feet.}$$

Fig. 279 represents a registering barometer made by M. Redier, of Paris, which is constructed as follows: In one branch of the ordinary siphon barometer is an ivory float $F$, on which is fastened a very light steel pointer, on the apex of which is an horizontal needle $A$. One end of the latter is made in a small hook, or catch. Affixed to the supporting-frame of the instrument is clock-mechanism. One train is terminated by a chronometer-escapement, and the other train by a light fly-wheel, which turns with great rapidity. The two trains are calculated so that the velocity of the fly-wheel may be double that of the escapement. A satellite gear unites these two movements, and on the axis of the satellite is carried a wheel, which engages with a pinion on which is mounted the large four-armed wheel shown. A chain from the latter moves the registering-pencil $K$ in one or the other direction, according as the wheel turns to the right or left. The axis of the large wheel has a pinion which engages in a rack not shown, whereby the plate which carries the barometer is moved; so that, when the pencil is caused to travel, the barometer is also moved in a vertical direction. The needle $A$ touches one of the wings of the fly-wheel with its hook-end. The escapement of the chronometer train works constantly, and so tends to carry the large wheel from right to left, and to raise the barometer upward. As the barometer is thus moved, however, the needle is disengaged from the fly-wheel. The latter is then free to turn, and, as its velocity equals 2, that of the escapement being 1, it draws the large wheel from left to right, and causes the barometer to descend. The needle then once more catches the fly-wheel.

When atmospheric pressure does not change, the pencil describes a right line; should it augment, however, the mercury sinks in the barometer, the needle is carried down, and the hook engages still further on the fly-wheel. It will then take longer for the escapement to cause the disengagement of the fly-wheel. Consequently the large pulley turns in the same direction for a period proportional to the change of pressure, and the mark left on the paper indicates this movement. If, on the other hand, the pressure diminishes, the fly-wheel is freed, and the separation between wheel and needle will be greater in degree proportional to the diminution of pressure. A movement of the pencil to the right, therefore, indicates a rise in the mercury; to the left, a fall.

The paper on which the indications are received is divided into spaces horizontally to represent

279.

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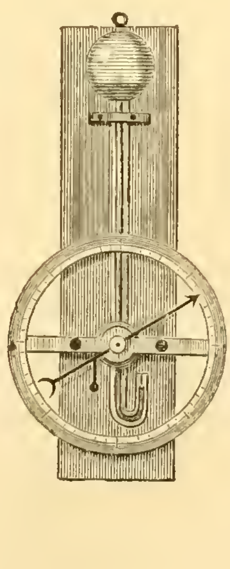

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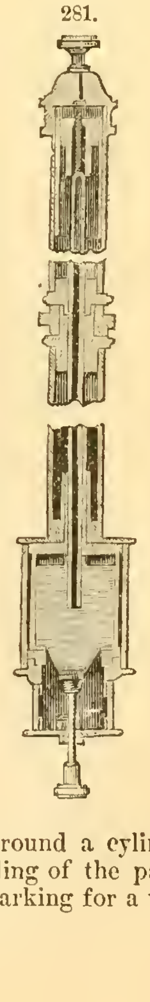


hours, and vertically to represent varying degrees of pressure. It is wrapped around a cylinder, which is rotated by clock-work $R$ over given distances, to correspond with the ruling of the paper. The length of the latter may comprise indications for several days, on which the marking for a week

is exhibited. The little hammer $O$ is caused to strike gentle blows on the barometer-support, so as to keep the mercury-column always free and lightly shaken.

A barometer in common use is provided with an index which turns round upon a dial, and points to figures which indicate the height of the mercury, as also to words descriptive of the state of the weather, as "Cloudy," "Fair," etc. The index is made to move by means of a string, which passes around its axle, and has at each end a weight attached, the larger one resting upon the surface of the mercury in the shorter limb of a siphon barometer. Fig. 280.

The words "Change," "Fair," and "Rain," engraved on the plate of the barometer, are calculated to mislead. In winter a fine bright day will succeed a stormy night, the mercury ranging as low as 29 inches, or opposite to "Rain." It is not so much the *absolute* height as the actual rising and falling of the mercury which determine the kind of weather likely to follow.

The simplest form of barometer is that called the cistern barometer. A straight Torricellian tube terminates at its foot in a cistern of mercury. By the rising and falling of the liquid in the tube, the level of that in the cistern must change. The absolute height of the mercury is found by making the scale fixed, and bringing the mercury to its zero-point by means of a scale which is made to press against a flexible bag that forms the lower part of the cylinder, as represented in Fig. 281.

BARRAGE. Barrage is a French term, and signifies, in an engineering sense, the barring or damming of a river or other water-course by artificial means, for the purpose of forming reservoirs for the supply of water to cities, canals, manufactories, etc.; or, in order to facilitate navigation or irrigation where the incline is too rapid, and the quantity of water, from that or other causes, would be insufficient for those purposes, were it left to spread freely and waste over its normal bed.

We shall include, in this article, structures of the nature of dams for the improvement of rivers and harbors, such as breakwater, jetties, etc.

*Barrages, or Dams.*—When erected for purposes of water-power or water-supply, the object of a dam is partly to make a store-reservoir, but principally to prolong a high top water-level from its natural situation at a place some distance up the stream to a place where water is to be diverted from the stream to drive machinery, or for some other purpose. When erected for purposes of navigation, the object of a dam or barrage is to produce a long reach or pond of deep and comparatively still water, in a place where the river is naturally shallow and rapid. In planning a dam or barrage, three things are to be considered: its line and position, its form of cross-section, and its construction.

I. Line and Position. It is best to avoid sharply-curved parts of a river-channel in choosing the site of a dam, lest the rapid current which rushes down its face in times of flood should undermine the concave bank. For the protection of the banks in any case, it is advisable so to form the dam that the cascades from the lateral parts of the crest shall be directed from the banks and toward the centre of the channel. This may be effected either by making the river slightly curved in plan, with the concavity at the down-stream side, or by making it like a V in plan, with the angle pointing up-stream. Another mode of protecting the banks is to make the crest of the dam slightly higher at the ends than in the middle, so that the lateral parts of the cascade may be too feeble to do damage.

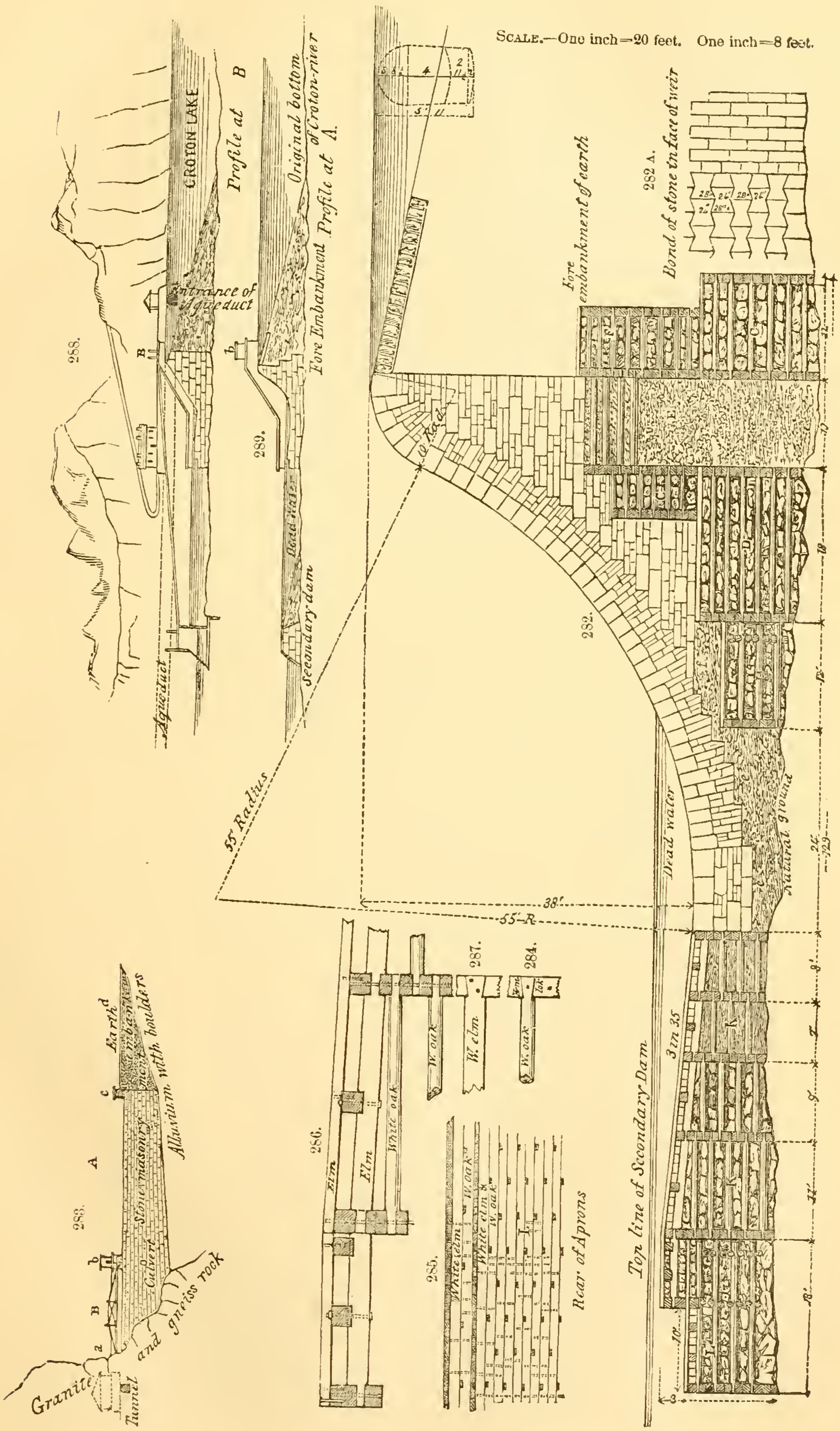
In order to diminish the height and extent of back-water during floods, the crest of the dam is often made considerably longer than the breadth of the channel. This is effected either by making it cross the channel obliquely, or by using the V-shape already described, the latter method being the best for the stability of the banks. The practical advantage of such increased length is doubtful.

II. Form of Cross-Section. The back or up-stream side of a dam is usually steep, ranging from vertical to a slope of about 1 to 1; the top is either level or slightly convex, and not less than about 2 or 3 feet broad. In designing the front or down-stream slope of a dam, the principal object is to prevent the cascade that rushes over it from undermining its base. The commonest method is to use a long flat slope of 3 to 1, 4 to 1, or 5 to 1, in order that the speed of the current may be diminished by friction, and that it may strike the bottom of the channel very obliquely. A further protection is given to the river-bed by continuing the front slope a short distance below the bottom of the channel, and then curving it slightly upward. Another method is to make the front of the dam present a steep or nearly vertical face, over which the water falls on a nearly level apron or pitching of timber or stone. Probably the best method would be to form the front of the dam into a series of steps, presenting steep faces and flat platforms alternately, the general inclination being about 3 to 1; thus a great fall might be broken up into a series of small falls, each incapable of damaging the platform which receives it.

III. Construction. Stone masonry well laid in hydraulic cement and framework of timber, or the two in combination, are the materials usually employed in the construction of dams of great strength. When dams for slack-water navigation are built upon streams which are subject to heavy freshets, the selection of the site is very important. It is generally advisable to place them where the stream is pretty wide, for the purpose of allowing a ready flow over the dam during high water. If built at a narrow place, the restraint to the outlet would so increase the hydraulic as well as the hydrostatic pressure, that great expense would necessarily be incurred in making a structure sufficiently strong and securely joining it to the banks, and in many cases the object could not be accomplished. In constructing a dam it must be borne in mind that the pressure of water is in proportion to its depth, but the circumstances not only vary with difference of location, but in the same location, in consequence of changes which constantly take place in the current of the stream. Often during a freshet the surface becomes exceedingly rapid, so as to exert great force against the upper part of the dam, and calculations based upon hydrostatic pressure alone would prove erroneous. The rule, therefore, is to supplement mathematical calculations by a judgment as to the requirements necessary in each particular case, and to make the structure strong enough at every point to withstand whatever force may be brought against it under any possible circumstances.

Fig. 282 represents a section of the dam across the Croton River, which supplies the city of New York with water. The base of this work is composed mostly of cob, or crib-work of logs or timber,

SCALE.—One inch=20 feet. One inch=8 feet.



their intervals being filled in with stone, and the intervals between the piers of crib-work with concrete. The upper portion, and the apron, or down-stream face of the dam, are made of cut stone. A secondary dam is constructed below, in order that the discharges or overflow of the water may fall into back-water, and in that way check the force of the current. Fig. 283 shows the profile of the river. At first a length of only 90 feet was given for the dam *B*, and this part was erected after the profile of Fig. 288, with a construction similar to that of Fig. 282, extending then only from *a* to *b*, Fig. 283, occasion for which was given by the rock lying here affording a good foundation; the remainder of the river profile to *d* was to be filled with an earth embankment. A considerable freshet, however, carried away this embankment when partly completed, and it was resolved to extend the stone dam 180 feet farther, to *c*. For the erection of this part, *A*, Figs. 282 and 283, the bottom of the river was cleared from mud and bowlders, and the piers *C* and *D*, of 12-inch hemlock timber, successively built up; the walls were connected by ties, and filled with stone closely packed in; the top was covered with 6-inch plank of white pine, and treenailed; upon this planking the timber-piers *F* and *G* were erected, but only *F* covered with plank. While erecting those piers, the space *E* was filled with concrete, and the piers near the top connected with ties. Both these piers, together with their filling of concrete, being the armature of the dam, served at the same time for a coffer-dam against the water above. Against *G* another timber pier was in like manner constructed, with but one timber wall; in place of the other, anchors of round timber were laid in, and with the ties joggled together. The timber of these piers is of hemlock, 12 inches by 12, the ties of white oak, 7 inches thick at the smaller end, framed with single dovetails 4 inches thick, Fig. 284, and fastened with 1-inch treenails, which are placed 10 feet from centre to centre. The pier-timbers, Figs. 285 and 286, are treenailed 30 inches deep, with 2-inch treenails of white oak. These nails are sometimes put nearer together, and the ties likewise. The planking is of white pine. When the timber piers had reached a certain height, the piers *K K*, of four compartments, were put down, two of which, the nearest to low water, were packed out with stone; the two others were filled with concrete, and formed the coffer-dam against the water below the dam. The courses were of 12 by 12 inch hemlock; the ties of oak, 8 inches at the smaller end, and 6 feet apart from centre to centre; the treenails of the squared timber the same. The uppermost of them are made of elm and white oak, treenailed every 3 feet, 30 inches deep, $2\frac{1}{2}$ inches in diameter. The upper ties, Figs. 286 and 287, are of elm 12 inches square; to this course of ties a bed-timber of white elm is joggled and secured by iron screw-bolts, Fig. 286. Across these bed-timbers or caps an apron-planking of 6-inch elm is fastened by $1\frac{1}{2}$-inch locust (*robinia pseudo acacia*) treenails of 13 inches in length. Against the rear of this timber pier the one marked *L* was erected; against the back-water only, it has a regular timber wall, Fig. 285; the ties are secured by anchors. A part of the apron-planking of this pier is laid horizontally in connection with the apron of the pier *K*; the remainder is put 3 feet lower, Fig. 282. After the pit had been laid dry by pumps, the ground and the space at *f* were filled in with concrete and leveled off. On this bed the body of the dam was by degrees erected of hydraulic stone-masonry, according to the bond, Fig. 282 *a*, and the courses of face-stone for the weir laid down. This face-work is of granite, cut with such closeness as to allow the stone to be laid with a joint not exceeding three-sixteenths of an inch. The masonry is laid in horizontal courses to 3 feet from the extrados of the face-work, where it is in courses corresponding with the radii. In front of the lip of dam below the head-water, a fore-embankment, Figs. 282, 288, 289, was formed of earth, and its upper part secured with a dry stone-pavement 2 feet thick.

In the part of the dam first erected, *B*, Fig. 283, at *b*, and Fig. 289, at *b*, a waste-weir is constructed, in order to draw off the water of the lake from a greater depth; it consists of a well with culverts having two sets of gates, all of which are protected with a small stone house, Figs. 283 and 289, at *b*, which can be reached by the bridge *B*, Figs. 283 and 288.

At a distance of 300 feet from the lip, a secondary dam, Figs. 288 and 289, is constructed; it is erected of round timber, filled up with dry stone. The object of this secondary dam is to divide the head of water, and, by means of the water-basin formed by it, to break the body of water running over the weir, and to keep the wood-work of the timber piers *K* and *L* under water. Near the left shore a waste-weir is constructed in this dam, in order to let off the water from the basin when required.

*Wooden Dams* are usually of crib-work, of either rough round logs with the bark on, or of hewn timber—in either case about a foot through. These timbers are merely laid on top of each other, forming in plan a series of rectangles, with sides of about 7 to 12 feet. They are not notched together, but simply bolted by 1-inch square bolts (often ragged or jagged) about 2 to $2\frac{1}{2}$ feet long, through every timber at every intersection.

The cribs are usually, but not always, filled with stone. In triangular dams, disposed as in Fig. 290, this stone filling is not so essential as in other forms, because the weight of the water, and of the gravel backing, tends to hold the dam down to its base. Still, even in these, when the lower timbers are not bolted to a rock bottom, or otherwise secured in place, some stone may be necessary to prevent the timbers from floating away while the work is unfinished and the gravel not yet deposited behind it. On rock, the lowest timbers are often bolted to it, to prevent them from floating away during construction; and when the water is some feet deep, this requires coffer-dams.

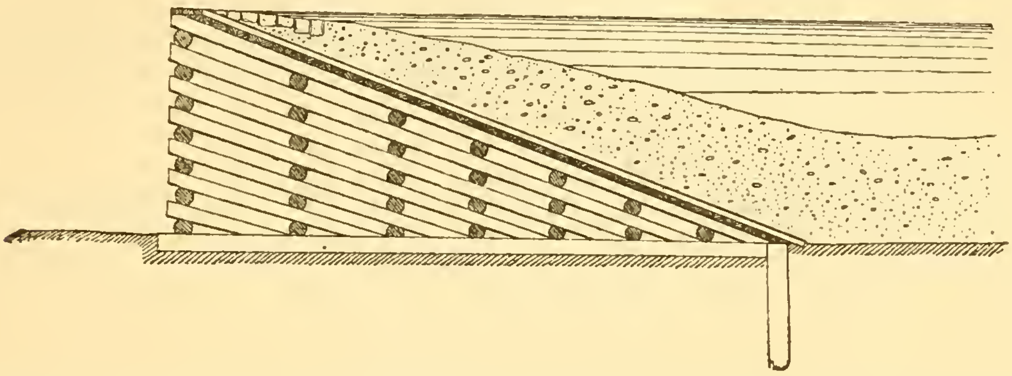
*Movable Barrage.*—A movable barrage, established across a navigable river, comprises two essential parts, namely, the navigable way and the overfall (Fig. 291). The former is used for purposes of navigation when there is a sufficient natural draught of water in the river for ships to pass; the movable lifts which serve to close the way are then laid flat on their platform. The overfall serves to maintain the level of the river at a determinate height when the barrage is in use; it likewise serves as an outlet for the water while the lifts of the navigable way are being raised.

In addition to these two essential parts, there is generally also a lock, through which the navigation takes place when the barrage is closed (Fig. 291). When there is no lock adjoining, then the

navigation can only be performed by removing the barrage and releasing the water at certain fixed periods.

The *sill*, or *platform*, of a navigable way should be placed at a depth not less than that of the bottom of the river above the weir. The sill of the overfall should be so raised that, having due regard to economy and facility of construction, its section, added to that of the navigable way, shall offer an outlet proportional to the quantity of water that flows down the river at its different periods.

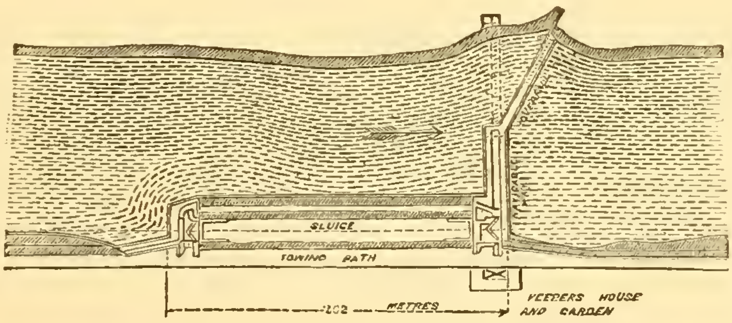
290.



Moreover, it must be at such a height that it may give free passage to the waters of the river while the lifts are being raised, without producing too heavy a fall from the upper to the lower basin. These conditions are most important.

The establishment of a navigable way is a costly work; its breadth should, consequently, not be greater than is absolutely necessary for the requirements of navigation. When the breadth of the river will not admit of the overfall being placed perpendicularly to its course, and in a line with the navigable way, it may be put obliquely; in that case the angle of inclination must not be less than 60 degrees.

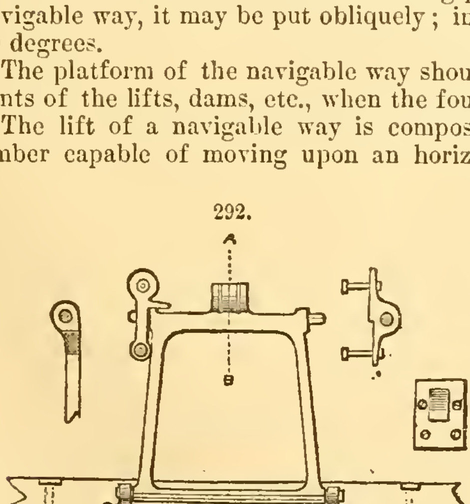
291.




The platform of the navigable way should be of sufficient width to receive all the various components of the lifts, dams, etc., when the foundations are laid upon concrete.

The lift of a navigable way is composed of three principal parts, viz.: 1. Of a framework of timber capable of moving upon an horizontal axis placed perpendicularly to the direction of the current. When this framework is raised, it is supported by its axis, while its base rests against a sill attached to the platform of the barrage. 2. Of a stay, made of iron, and bearing the horizontal axis mentioned above. The lower part of the stay is terminated by two spindles, working in sockets, that are attached to the sill against which the foot of the lift rests (Fig. 292), so that this stay is able to turn upon its base, carrying with it, as it moves, the framework of the lift. 3. Of a buttress of iron, the head of which forms an articulation with that of the stay, its foot resting against a cast-iron shoe firmly cemented in the platform.

292.

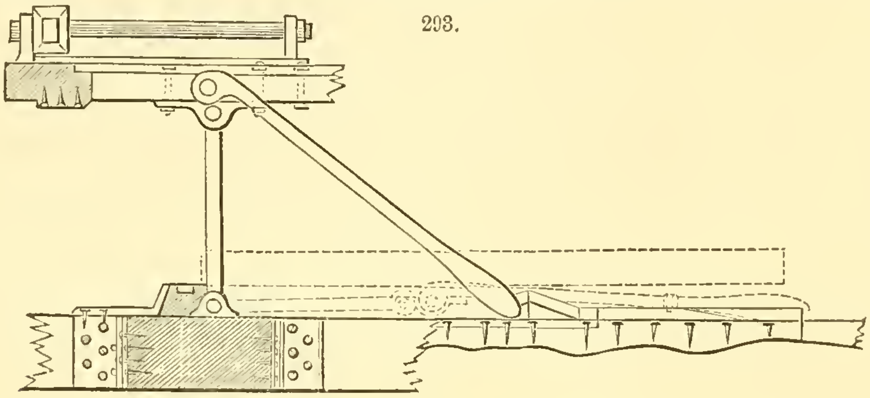



These three pieces are all that constitute the lift, and the whole arrangement presents very much the appearance of a painter's easel with a picture upon it. This is the system that has been so successfully and ingeniously put into practice by M. Chanoine, at the celebrated barrage of Conflans-sur-Seine, and at other places.

Besides the three principal components of a lift, above described, there remains yet one addition of some import:

*The Counterpoise.*—Upon referring to the several illustrations, it will be observed that that portion of the lift which is above its axis of suspension, and which is called the "fly," is wedge-shaped, getting thinner toward the top; whereas that which is below the axis of suspension is uniform in its thickness, which is equal to the thickest part of the fly. This is done in order to nearly balance the

gate, giving the lower portion, however, a slight preponderance over the upper, which has a longer radius. The moment of the weight of the timbers forming the lower part, called the "breech," is about 110 feet out of water, and that of the timbers of the fly is nearly equal to it; but when the breech is entirely immersed, the moment of its weight is destroyed by the very fact of immersion; so that, in manœuvring, the weight of the fly becomes an obstacle to the lowering of the breech. To remedy this, it was necessary to append a counterpoise to the latter, composed of a mass of cast-iron, movable, and held and girded by three parallel iron bars (Figs. 293, 294) along which it may slide, and weighing about 145 lbs. In order to give some idea how the system operates, let us suppose a lift to be raised, and in position, and then observe by what means it is lowered. If the end of the buttress, which is rounded, be drawn on one side from the shoe, it is evident that, losing its point of support, it will slide upon the platform in the direction of the pressure against the lift;


293.

that the "stay" will necessarily follow the buttress, turning upon its base; and that the gate itself, in rotation, will follow the stay; so that the two former will be stretched upon the platform in prolongation of one another, while the latter rests on the top of both, covering them.

The buttresses are made to slip from their respective shoes by means of an iron bar, placed horizontally upon the platform, and furnished with catches, so disposed at distances that they draw aside the buttresses one by one in succession, and in the order in which it is intended to lower the lifts. This bar must be easy of management, and arranged in such a manner that its action may not be impeded by gravel, sand, or any foreign matter carried down by the current. It is terminated at one end by a rack worked by a vertical wheel, by the aid of which its motion is imparted, and thence transmitted from buttress to buttress. Upon being released from the shoe, the buttresses slip into guiding-rails, or grooves, in which they slide till they reach the bottom. We have already implied that the lift proper is divided by its axis of rotation into two distinct parts: the lower part it has been agreed to call the "breech," and the upper the "fly." It is necessary to bear in mind this distinction. We will now describe the

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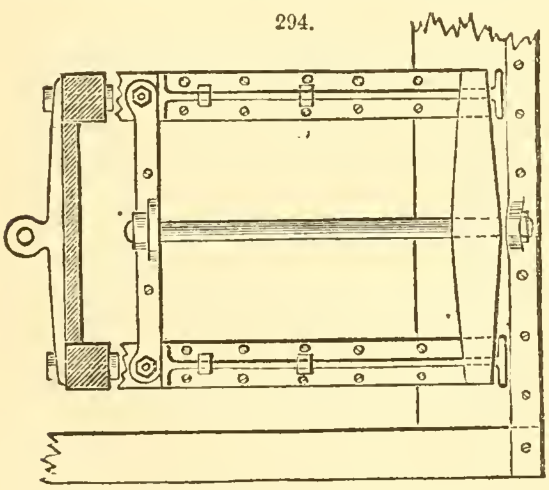


*Method of Raising the Lifts.*—The base of the breech is provided with a stout iron handle. The keeper, entering a boat fitted for the purpose, seizes this handle with a hook; then, pulling, by degrees the breech of the lift rises from the platform at the end of their course, the extremity of the buttress comes and rests against the shoe, and the gate remains suspended on its axis of rotation, while the breech is upheld by the boatman's hook. As soon as the hook is detached, if the breech be a little heavier than the fly, or if it be slightly pushed, the gate immediately turns upon its axis, and the breech rests against the sill of the weir.

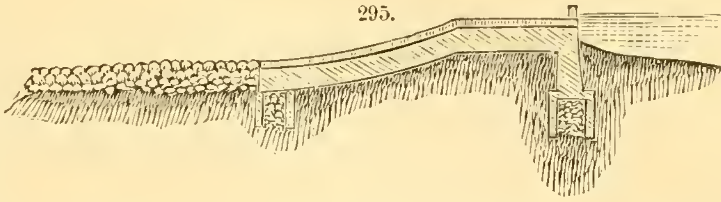
This, in effect, is what takes place; but, in order to insure precision and regularity in the different parts, many other accessories are needed, the details of which our limits will not allow us to particularize.

Barrages for Purposes of Irrigation.—It is only in Eastern countries that the opportunity occurs, or the necessity exists, of carrying out irrigation-works on a gigantic scale. Native works in the deltaic provinces on the great rivers of Southern India have been in successful operation for centuries. The basis of these works has been in nearly every instance the damming of the rivers at the apex of the delta by means of an anicut, or barrage, in such a manner as to raise the low-water level to the extent required for irrigation by gravitation, but at the same time without appreciably augmenting the heights of great floods.

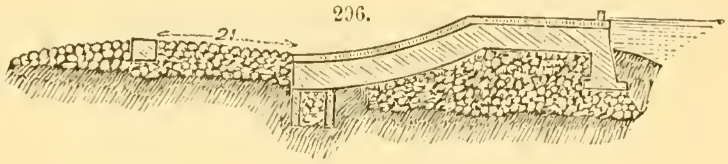
One of the longest of the Indian barrages—that on the Godavery River, at Dowlaisweram—is described as follows by Col. Baird Smith, R. E., in his well-known report on Indian irrigation:

"The bed of the Godavery is throughout of pure sand, and in such soil are the whole of the foundations laid. Commencing from the eastern or left bank, the first portion of the work is the Dowlaisweram branch anicut, or dam. The total length of this is 4,872 feet, or 1,624 yards. The body of the dam (Fig. 295) consists of a mass of masonry resting on front and rear rows of wells, each well

being 6 feet in diameter, and sunk 6 feet below the level of the deep bed of the stream. The masonry forming the body is composed: 1. Of a front curtain-wall running along the whole length, 7 feet in height, 4 feet in thickness at the base, with footings 1 foot broad on each side to cover the tops of the wells on which the curtain-wall rests, and 3 feet thick at the summit. 2. Of an horizontal flooring or waste-board, 19 feet in breadth and 4 feet in thickness. 3. Of a masonry counter-arched fall 28 feet in breadth and 4 feet thick, of which the curve is so slight that the form may be considered practically as that of an inclined plane. The waste-board and tail-slope are protected against the action of the stream by a covering of strongly-clamped cut stone over all. 4. Of a rough stone apron in rear, formed of the most massive stones procurable, and extending about 70 or 80 feet down-stream. This protects the rear foundation against the erosive action of the stream passing over the dam, and may be extended as circumstances may require. The body of the dam rests merely on a raised interior embankment or core of the common river-sand, and no precautions to strengthen this in any way have been considered necessary. On the extreme left flank of the dam is a series of works, consisting of a lock for the passage of craft, a head-sluice for an irrigation-channel, and an under-sluice for purposes of scour and clearance from deposits.


295.

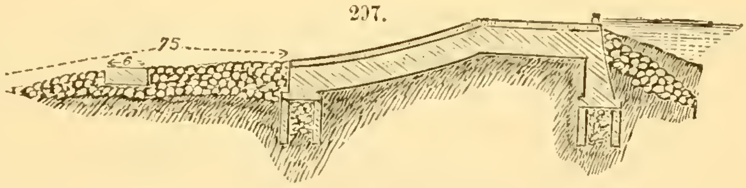
"The second branch of the river is called the Rallee branch, and is barred by an anicut or dam 2,862 feet, or 954 yards, in length. In section (Fig. 296), this work differs a little from that just described. The general dimensions of the bodies of both are similar; but the front curtain-wall of the Rallee dam, instead of resting on a row of wells, is founded on a mass of rough stone, and this mass extends under the waste-board or sill, and part of the curved tail, thus replacing the core of river-sand characteristic of the Dowlaisweram branch anicut by one of a more substantial kind. The rear foundations consist of a row of 6-foot wells as before; and the only difference in the rough stone rear apron is the insertion along its length of a retaining or bonding bar of masonry 4 feet in breadth by 3 in depth. The left-flank revetments are similar, though not quite so long as those formerly described. On the right flank is an under-sluice with 8 small vents of 6 feet each, and 2 large arches carrying a roadway for cross-communication.



296.

"The length of the Muddoor branch dam, the third section of the great work, is 1,548 feet, or 516 yards. Its section is precisely the same as that of the Dowlaisweram dam; it has the same front and rear foundations on wells, the same dimensions of the masonry-body, which rests on a like core of river-sand without any intermixture of heavy material.

"The length of the Vegaishweram branch dam, the last of the series, is 2,584½ feet, or 861½ yards. In section (Fig. 297) it presents several small differences from any of the others. Its height at the sill is 1 foot greater than the other; the thickness of the masonry of the body of the dam 6 inches, the breadth of the sill 3 inches, and that of the tail 9 inches, more than the corresponding details for the other portions. The foundation and core of sand within the body are like those of the Dowlaisweram and Muddoor dams, but the front curtain-wall is protected by an apron of rough stone about 10 feet deep and 6 or 7 feet wide, carried along its entire length. The rear rough stone apron is banded and strengthened at 20 feet from the termination of the masonry-tail by a bar of stone in mortar 6 feet wide by 2½ feet deep. With these differences in detail, the general arrangements are the same as in the other branches.



297.

"Viewed as a whole, therefore, the Godavery anicut consists of a masonry-dam in separate portions, the united length of which is 11,866½ feet, or 3,955½ yards, being very nearly 2¼ miles of river channel blocked up by a solid, substantial, well-protected mass of stone in lime cement, or without it, according to position, having a total breadth of base equal to very nearly 130 feet, and height of crest or sill equal to 12 feet."

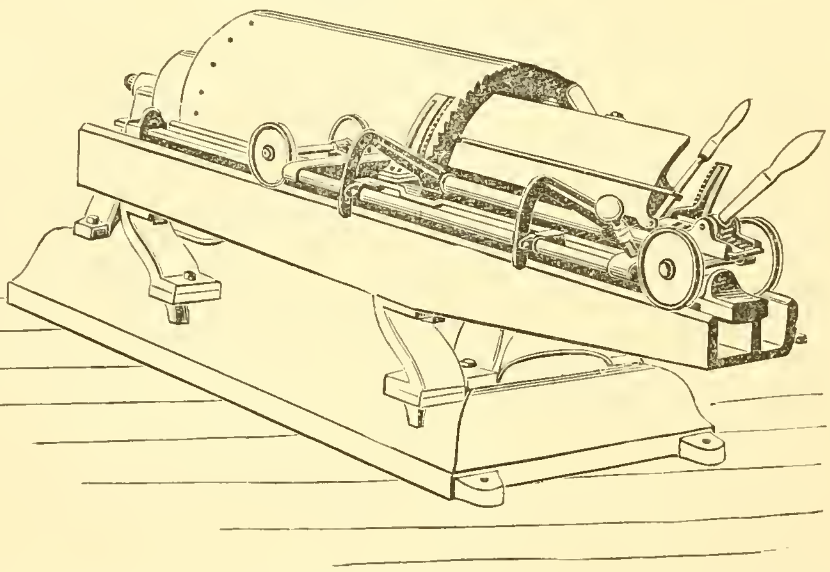
*Works for Reference.*—"Cours de Mécanique Appliquée," Brerse; "Expériences Hydrauliques sur les Lois de l'Ecoulement de l'Eau," Lesbros; "Notice sur les Barrages Mobiles," Chanoine; "Principes d'Hydraulique," Dubuat; "Mémoire sur les Barrages à Hausses Mobiles," Chanoine and Lagrené; "Rapport sur la Forme et la Mode de Construction du Barrage d'Enfer sur le Furens," Graeff, *Mémoires des Ponts et Chaussées*, 4th series, No. 134; "Cotton Cultivation and Barrage of Great Rivers," Gibbs, 1862; "Mémoire sur les Barrages," Breton, 1867; "Barrages Aiguilles, Système Poirée," Saint-Yves, *Mémoires des Ponts et Chaussées*, 1870, tome xx., 4th series; "Irrigation in India," *Mémoires des Ponts et Chaussées*, 1871, tome ii., 5th series; "Mémoire sur un Nouveau Système de Barrage," Bonté, *Mémoires des Ponts et Chaussées*, 1876, tome xi., 5th series; "Construction of Mill-Dams," Leffel, Springfield, O., 1874; "High Masonry Dams," McMaster, New York, 1876. An excellent discussion of the different systems of hydraulic gates and movable dams will be found in report of Chief of Engineers U. S. A., 1874, part i., p. 415; see also report of Chief of Engineers

for 1875, for barrage at Port à l'Anglais on the Seine, and for M. Girard's automatic movable dam; also see report for 1873, part i., p. 61, and part ii., p. 640; for barrage of the Nile, see *Engineering*, vol. xxi., p. 40, *et seq.;* also "Construction of High Masonry Dam" (Croton), *Engineering*, vol. xx., p. 175.

BARREL-MAKING MACHINERY. The machines which are used in the manufacture of barrels may be divided into three classes, namely: those employed for cutting and dressing staves; those used for making the heads; and those adapted for finishing the barrel after portions of its parts have been assembled. All of this machinery may also be grouped in two classes, according as the work to be produced is a tight barrel or cask, such as is employed for containing liquids, or a slack barrel for holding flour, sugar, cement, or other dry substances. The devices for making kegs and small casks may also be separately classified, as in many respects their construction differs in matters of detail from that of barrel-machinery.

1. *Stave-Machinery.*—The principal manipulations of the stave are jointing, dressing, equalizing, and sawing. In the jointing machine, the stave is tightly held in clamps, and by pressure on a foot-treadle moved up to a disk, on the face of which are radially disposed knives which bevel off the edges of the stave to the proper degree for fitting it into the cylindrical barrel. With this machine a fan-blower is combined, so that all dust and shavings are rapidly removed as fast as produced. When the stave is jointed, the relaxation of pressure on the treadle causes its release. Arrangements are provided for tightly holding the work, and also for giving to the edge any desired bilge or bevel. The machines employed for dressing sawed staves consist of a rotary cutting-head and a carrying or revolving bed, with feed-rollers which compel a strong forward motion. The stave is placed upon the bed and carried under the rollers, which are straight or convex to fit the shape of the work. The rotary head and cutters are so made and ground that the stave is smoothly finished and a uniform thickness given. For dressing rived and sawed staves of all thicknesses, a special machine has been devised, which dresses both sides of the stave at the same time without cutting the wood across the grain; that is, it leaves the staves winding and crooked as they were rived from

298.



the block. This is accomplished by allowing the frame which supports the cutters to oscillate and rock in all directions, so that the cutters adapt themselves to all the crooks and winds of the stave.

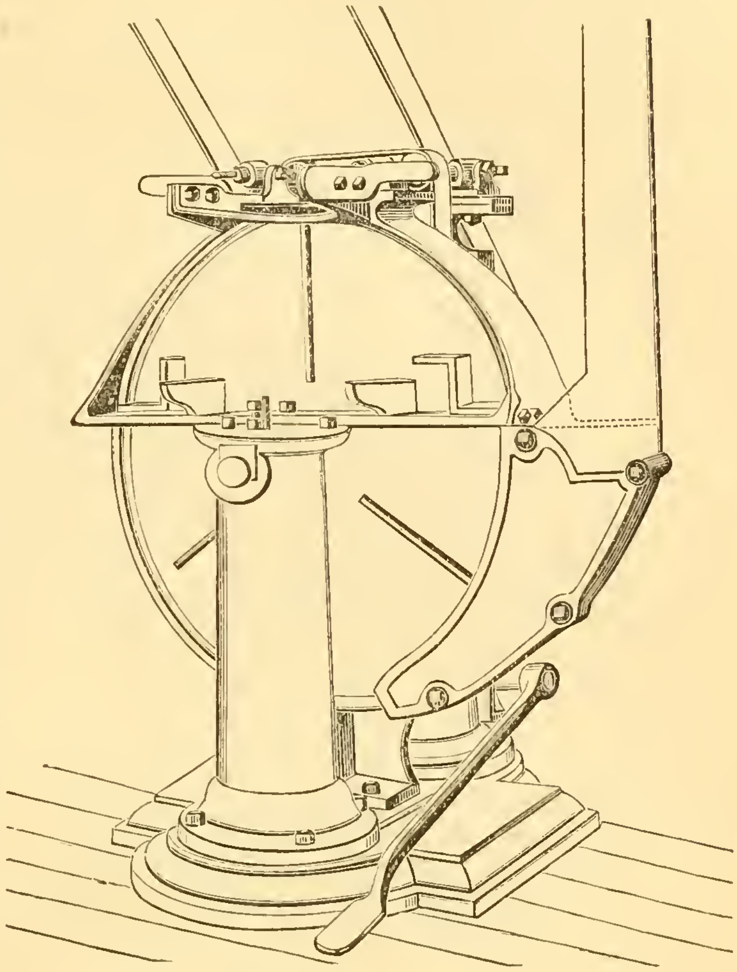
For sawing staves, the cylinder-saw machine represented in Fig. 298 is employed. This machine cuts the stave, which is suitably clamped and fed forward, in circular form. The construction is obvious from the engraving.

In order to saw the staves to uniform length, the stave-equalizer is employed. The staves are placed upon a conveyer consisting of two endless ropes, by which they are brought upon the peripheries of two wheels on the same shaft, so that each stave rests across projections on the rim of the wheels. As the wheels rotate, the ends of the stave are brought in contact with two circular saws, which are adjusted at a distance apart equal to the desired length of the stave. The feed being continuous and the operation of the machine automatic, it is only necessary to place the staves on the conveyer, when they are rapidly conducted to the saws.

2. *Head-making Machines.*—For ordinary casks the heads are usually made of several portions jointed and doweled together. To make the joints and prepare the pieces of heading which have previously been sawn to the proper length for the dowels, is the object of the machine represented in Fig. 299. This consists of a large rotating metal disk, in the face of which are fixed three cutters, relatively equidistant. In front of the disk is a standard and rest. Upon the latter a piece of rough heading is laid, and its edges are pressed against the disk by hand, so that they are thus rendered perfectly smooth and straight. The work is then removed and laid upon another rest on top of the machine, where it encounters two swiftly-revolving bits, which are forced against the edge by the foot-treadle, and which speedily bore holes for the dowels. The disk acts as a fan, blowing away chips and shavings through the shoot shown at the right of the engraving. The heads of a large number of barrels can thus be prepared in a day by a single man, and the joint-knives are so arranged that either a hollow or straight joint can be made, as desired. The dowels are next in-

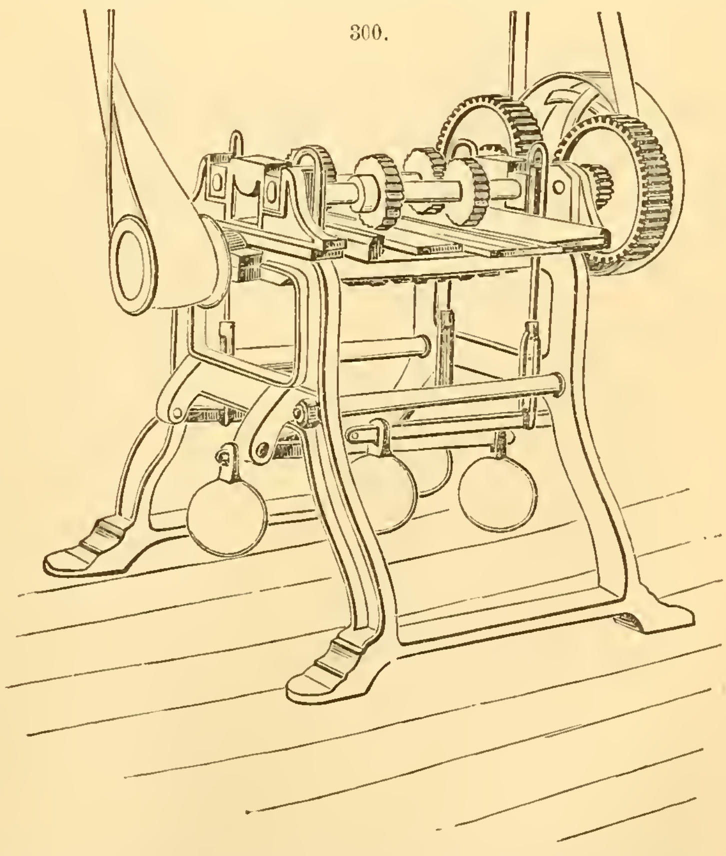
serted by hand, and the separate pieces put together, forming rough squares, ready for the next process. This consists in leveling, facing, and dressing the material on one side; and it is accomplished by a special machine shown in Fig. 300. The head is placed in front of a planer-cylinder on which are several blades, and which is swiftly rotated. The revolution of the corrugated feed-rolls carries the head over the planer-knives, which rapidly smooth off the under side at the rate of from 15 to 25 heads per minute.

299.



The next operation is turning the heads in circular form, and at the same time beveling the edge with two bevels, the upper bevel being less than the lower one. The machine employed is represented in Fig. 301. The head is placed between two disks, one of which, that on the right in the engraving, is provided with a number of spring pins near its periphery, which press the work against the opposite disk. The pin-disk is not connected with the driving machinery. Its spindle enters the cylindrical standard on the right, in which is placed apparatus by means of which the disk is thrown forward and locked in that position, firmly holding the work. Through the rotation of the opposite disk, the pin-disk is also carried round, but for only one revolution, at the end of which stop mechanism in rear of the standard is actuated to unlock the clamp, so that the pin-disk springs back and allows the work to fall out. The saw is mounted on a separate carriage, and has its own belt. On one side of the blade are secured two peculiarly arranged knives, by which, when the cutting mechanism is moved up against the edge of the head by the foot-treadle, both sides are cut at once, and at the same time through its rotating the work is turned in circular form. The machine is so constructed that all kinds and sizes of heads can be made with one and the same concave saw. An attachment is provided for giving the heads an oval form to compensate for shrinkage of material.

300.

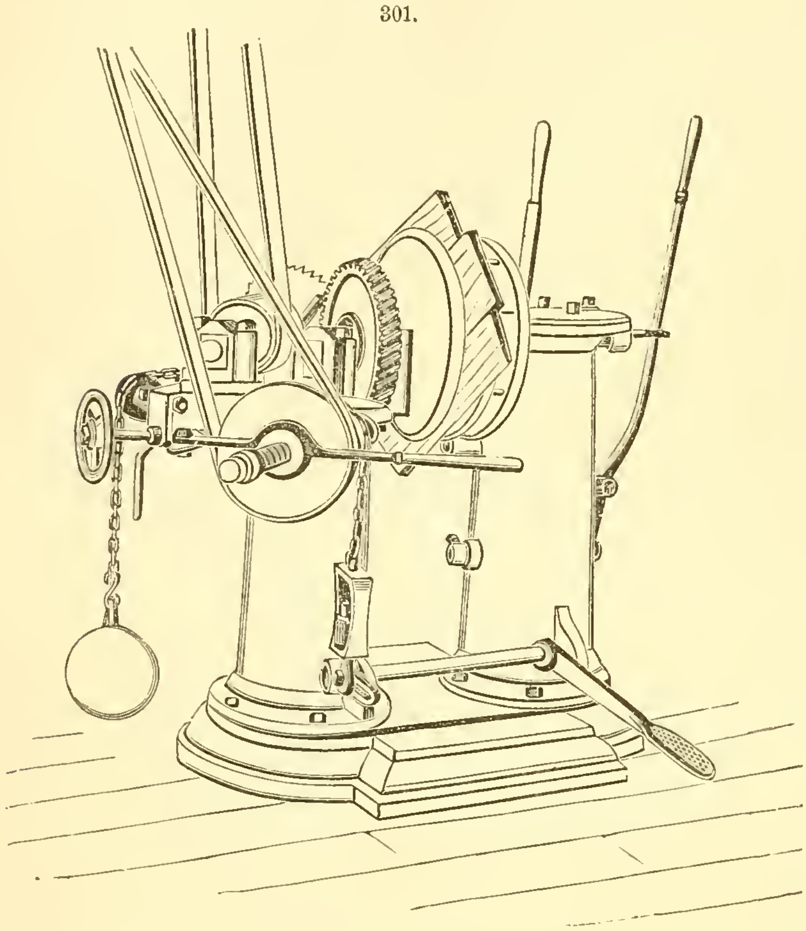


3. *Barrel-finishing Machines.*—Before being placed in these devices, barrels are "set up." The setting-up form is composed of two heavy circles of iron secured together and bolted to the floor; from these rise short standards which support a hoop. The staves are set in between the iron circles, and fitted carefully together. The iron truss-hooks, which are previously placed in proper position, are lifted up by hand so as to embrace the lower portions of the staves and hold them in place, when the whole is lifted out of the frame. One half of the barrel is now tightly held together, but the remainder is still open and flaring. To secure this in similar manner, a rope is passed around the flaring ends and taken to a hand windlass, by which the staves are brought together. The truss-hoops are slipped over the extremities, and the barrel is

ready to be heated in order to cause its staves to assume the curved form. The heaters are simple iron cylindrical stoves, over which the barrel is set, the top of the latter being closed with a sheet-iron cover.

The barrel is next leveled. To this end it is placed between two disks, one of which by suitable mechanism is moved forward, powerfully compressing the cask endwise and thus leveling the staves. It then goes to the trussing machine, which is represented in Fig. 302. Here the barrel is placed on end, and is surrounded by several hooked bars *A*, which usually protrude up through the floor of the shop. The longer arms catch above the upper truss-hoops, and sliding collars on these arms similarly catch on the second bands. The lower hoops are pressed against notched standards *B*, which also stand up above the floor, but do not pass through the same. The arms are pulled down by steam power, forcing the heavy rings over the bulging portion of the cask, and thus wedging them tightly in place. The same effect is produced by the stationary short lower standards, by their resistance to the lower hoops moving them as the barrel is forced down.

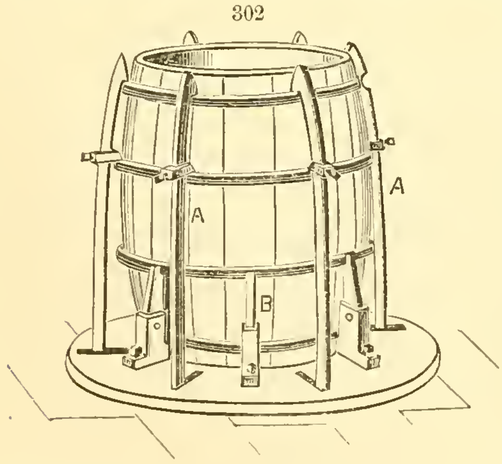
301.



In Fig. 303 is represented a machine specially designed for both leveling and trussing slack barrels, or, in other words, performing both of the operations just described. In this the arms *A*, which hook upon the rings, are all connected with the leveling disks *B*, and, by means of handles *C* on each of the latter, are all opened at once. The barrel with the truss-hoops on is then inserted, and a pressure of the foot-treadle closes all simultaneously. By means of the clutch-lever *D* the machine is then thrown into action. The pulley-shaft actuates (through gearing) a screw-shaft, which forces the movable disk toward the stationary one, thus, through the drivers, pushing the truss-hoops to their proper places on the barrel, and at the same time leveling the ends of the staves.

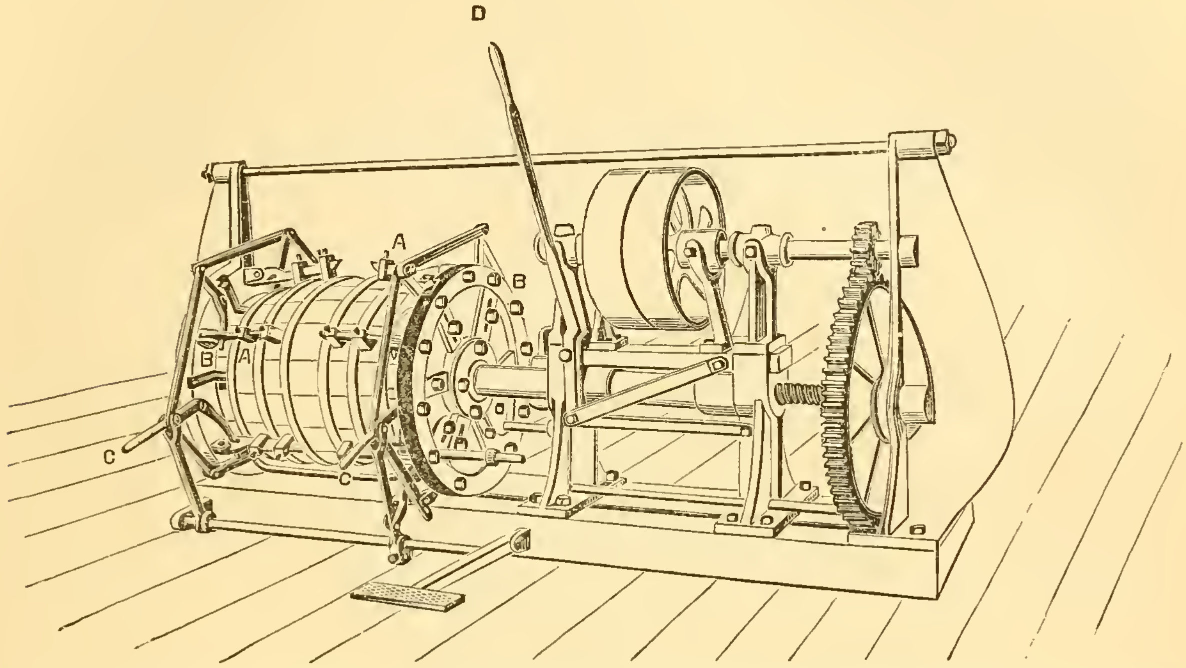
Before the heads are put in, each barrel at each end must be *crozed* and *chamfered;* that is, a groove must be cut around the inside, a short distance below the edge, while the latter must be beveled off. The ends of all the staves must be cut off perfectly true, and in heavy casks it is necessary to cut a *howel* or wide semicircular indentation around just below the croze. Fig. 304 represents a machine which chamfers, howels, levels, and crozes casks of imperfect periphery, finishing both ends at once. The barrel, being previously placed on supporting skids, passes directly between the chuck-rings, and its ends fit into the peripheries of the cog-wheels which work within the former. The wheel *A*, through suitable gearing, governs the backward and forward motion of the right-hand ring *B*. The other chuck-ring is stationary. As the barrel rolls into place, the operator moves up the ring *B*, thus confining it; and by suitable mechanism the barrel is caused to revolve. The cutters *C*, which are all fastened on two circular heads (the shafts of which are mounted on vibrating carriages and revolved by the smaller belts represented), are then moved up against the inner edge of the barrel. A single revolution suffices to perform all the operations above named, when the ring is drawn back and the barrel is removed. Each cutter-head is controlled by a rest upon the outside, thus compelling a uniform thickness and depth of chime, while the same is leveled with accuracy. The heads are usually inserted and the hoops placed in position by hand. The final smoothing of the barrel before all the hoops are in place is also done by machinery. The barrel is caused to revolve under a plane which serves as a smoothing tool, and the latter held so as to be easily guided by the attendant.

302



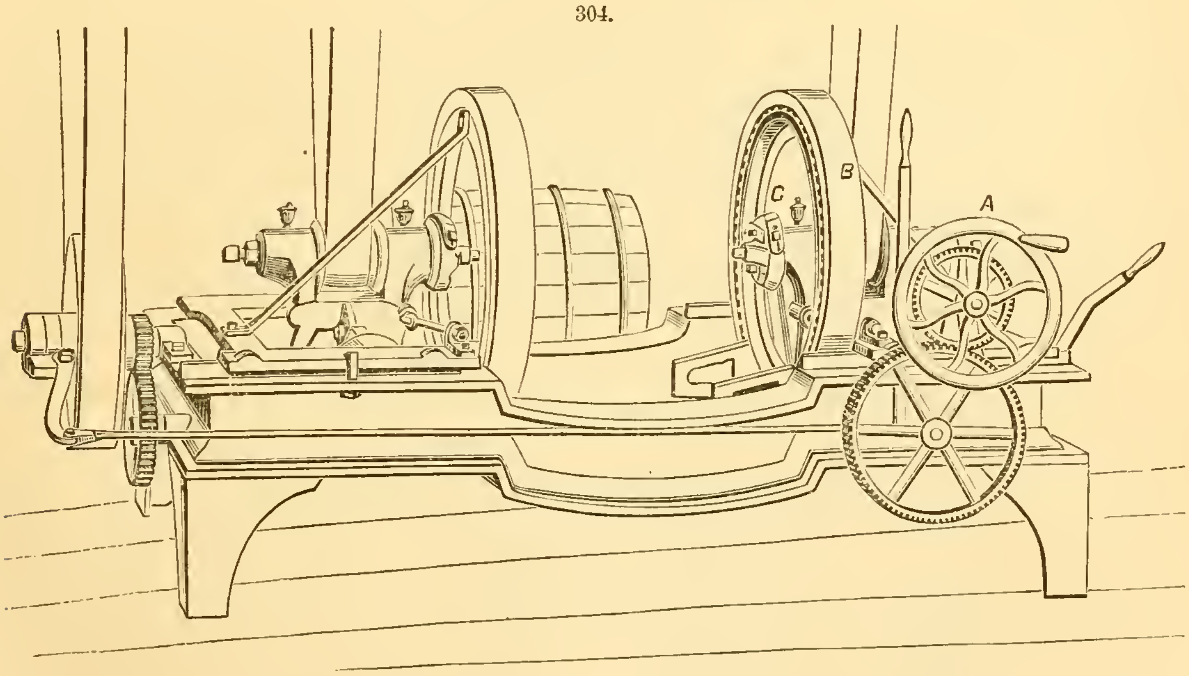
Among other machines specially used in barrel manufacture are apparatus for punching, flaring, and riveting iron hoops. This is done by rolls, which may be adjusted to give the flare as the hoop is

303.




passed between them; and on the same frame which supports these rolls is a lever carrying punches and a riveting press. There is also a distinct line of smaller machines designed for keg-making, the

304.



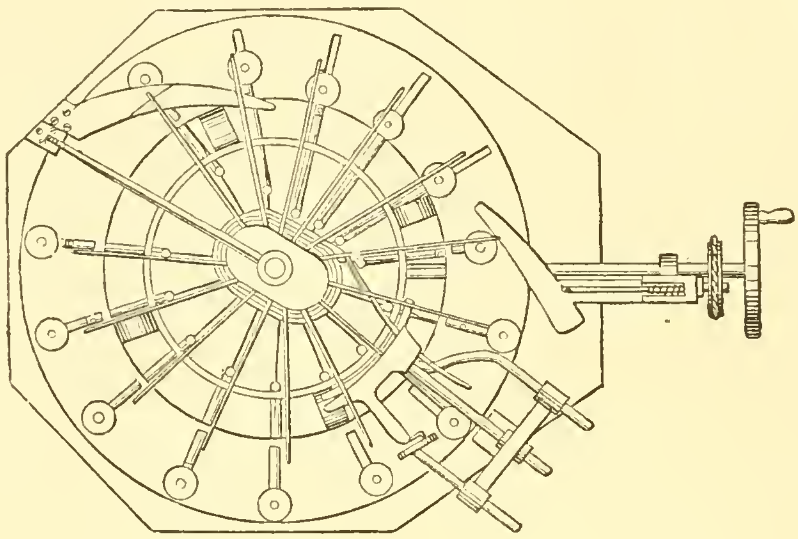

principles of the construction of which are essentially the same as those of the larger machines. All the apparatus above described is the invention and manufacture of Messrs. E. & B. Holmes, of Buffalo, N. Y.

The machinery used for barrel-making in Europe varies in many respects from that employed in this country. A complete description of it will be found in *Engineering*, xxi., 454. For further details of the American machines, see *Scientific American*, xxx., 191, and xxxii., 79.

BASKET-MAKING. In making baskets, the twigs or rods of split hickory, oak, black ash, or osier, being assorted according to their size and use, and being left considerably longer than the work to be woven, are arranged on the floor in pairs parallel to each other and at small intervals apart, and in the direction of the longer diameter of the basket. Then two large rods are laid across the parallel ones, with their thick ends toward the workman, who is to put his foot on them, thereby holding them firm, and weave them one at a time alternately over and under those first laid down, confining them in their places. This forms the foundation of the basket, and is technically called the "slat" or "slate." Then the long end of one of these two rods is woven over and under the pairs of short ends, all around the bottom, till the whole is woven in. The same is done with the other rod, and then additional long ones are woven in, till the bottom of the basket is of sufficient

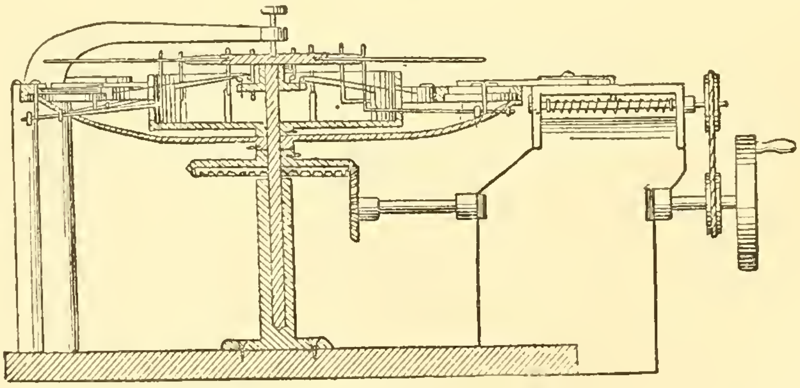
size. The sides are formed by sharpening the large ends of enough stout rods to form the ribs, and plaiting or forcing the sharpened ends into the bottom of the basket, from the circumference toward the centre; then raising the rods in the direction the sides of the basket are to have, and weaving other rods between them till the basket is of the required depth. The brim is formed by bending down and fastening the perpendicular sides of the ribs, whereby the whole is firmly and compactly united. A handle is fitted to the basket by forcing two or three sharpened rods of the right length down the weaving of the sides, close to each other, and pinning them fast about two inches below the brim, so that the handle may retain its position when completed. The ends of the rods are then bound or plaited in any way the workman chooses. This is a basket of the rudest kind. Others will vary according to the artist's purpose, skill, and materials. When whole rods or twigs are not adapted to the kind of work required, they are divided into splits and skeins. Splits are made by

305.



cleaving the rod lengthwise into four parts, by means of an implement consisting of two blades, crossing each other at right angles, the intersection of which passes down the pith of the rod. These splits are next drawn through an implement resembling a common spoke-shave, keeping the pith presented to the edge of the iron, and the back of the split against the wood of the implement. The split is then passed through another implement, called an "upright," to bring it to a more uniform shape. This consists of a flat piece of steel, each end of which has a cutting edge, like that of an ordinary chisel; this piece is bent round, and the edges are made to approach each other as near as desired by means of screws, the whole being fixed into a handle. By passing the splits between these two edges, they are reduced to any required thickness. The implements required in basket-making are few and simple, consisting, besides those just mentioned, of knives, bodkins, and

306.



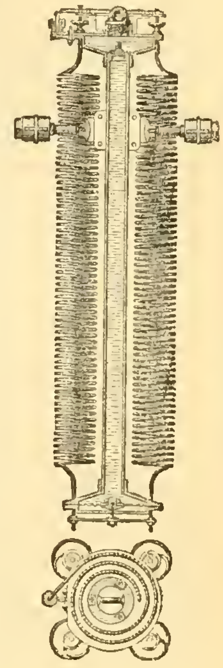
drills for boring, leads for steadying the work while in progress, and when it is of small dimensions, and a piece of iron called a "beater."

The splints of various kinds of wood, particularly certain species of ash, elm, and birch, are extensively employed in basket-work. These splints are obtained by beating logs of the wood with a maul, thus loosening and separating the different layers or rings into narrow strips. This is the simple and primitive process, and is necessarily slow, and restricted to woods of a free texture. Several machines have been invented and are now employed for the manufacture of splints, by which different kinds of wood, prepared by steaming or otherwise, are cut or rived into the required form. "Basket-willow" and "osier" are terms commonly applied to the species of *salix* most used in basket-work.

Figs. 305 and 306 represent a basket-making machine. A circular wooden bottom-piece with radially projecting basket-strips is attached to the end of a rotating shaft, and during the rotation of the bottom and radial strips a filling-carrying device having a vibratory motion passes over and

under the radial strips, and leaves the filling carried by it. This filling is laid in compactly by reed-like pieces. In the machine represented, the skeleton of a top or bottom is clamped to the shaft by set-screws. The end of the filling is fed through the apron. Motion is applied to the driving-shaft which rotates the skeleton. The pad of the apron is vibrated by the action of the eccentric-wheel that rests upon the ring, causing the rods to vibrate alternately above and below the filling between them (Fig. 305).

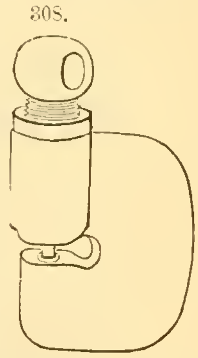
307.



BATHOMETER. An instrument for measuring the depth of the sea without the use of a sounding-line. The principle upon which the action of the bathometer invented by Dr. C. William Siemens depends is the diminution of the influence of gravitation upon a weighty body produced by a decrease in the density of the strata immediately below it; thus, the density of sea-water being about 1.026, and that of the solid constituents which form the earth about 2.75, it follows that an intervening depth of sea-water must exercise a sensible influence upon the total gravitation if measured on the surface of the sea.

The instrument, which is represented in Fig. 307, consists essentially of a vertical column of mercury contained in a steel tube having cup-like extensions. The lower portion is closed by means of a corrugated steel-plate diaphragm, similar in construction to those employed in aneroid barometers (see Barometer); and the weight of the mercury is balanced at the centre of the diaphragm by the elastic force of carefully-tempered steel springs, the length of which is the same as that of the mercury column. Both ends of the column are open to the atmosphere, so that its variations of pressure do not affect the readings of the instrument. The ratio between the areas of the cups and that of the tube is governed by the diminution of the density of mercury due to dilatation on increase of temperature, and the diminution of elasticity of the springs, due also to rise of temperature. The reading of the instrument is effected by means of electric contact between the centre of the diaphragm and the end of a micrometer screw, the divisions on the rim and the pitch of the screw being so proportioned that each division represents one fathom of depth.

308.



BATTERY. See Electro-Galvanic Battery, Stamps (for ore), Ordnance, and Thermopile.

BEAMS. See Strength of Materials.

BEAR, PUNCHING. A machine for punching metals by hand-power. The usual form is represented in Fig. 308. The punch is contained in the end of the screw, which is operated by means of a bar or lever passed through the hole at the head. The utmost capacity of this tool in practice is to punch a hole three-quarters of an inch in diameter through an iron plate five-eighths of an inch thick.

BEARINGS. By the term "bearings" is meant the surfaces of contact between the moving piece and its support. For motion of straight translation, the surfaces of the bearings must have a circular, square, triangular, or other straight-lined cross-section, and be perfectly straight in the direction of motion. Such bearings are called *slides*, examples of which may be seen in lathes, shaping machines, and many steam-engines. For rotary or turning motion, the surfaces of bearings must be surfaces of revolution accurately turned, as cylinders, spheres, cones, etc. The surface of the moving piece is called a *journal* or *neck*, and the fixed or supporting piece is also called a *journal*, *gudgeon*, *pedestal*, *plumber* or *pillow block*, *bush*, *step*, or *pivot*. These bearings provide also for rocking. For helical or screw motion the bearing must be an exact screw. The supporting piece is called a *nut*. These provide for rotation about a fixed axis, and for translation along it. The construction of one form of the phonograph necessitates this bearing, and other examples will be seen in the screw-cutting lathe, in various feed-motions of machine tools, etc. All bearings must so fit that the intensity of the pressure will not force out the material employed in lubrication.

For lubrication and friction of bearings, see Friction and Lubrication. See also Journals, Pillow-Blocks, Bush, Steps, Hangers, and Shafting.

BELLS. The alloy of which bells are made consists of copper and tin. 75 parts copper to 25 tin is a usual proportion, but the constituents vary from 50 copper, 33 zinc, and 17 tin, to 80 copper, 10 tin, 6 zinc, and 4 lead. Sometimes the proportions 72 copper, 26.5 tin, and 1.5 iron, have been employed. The various parts of a bell are the clapper or tongue, the clapper-bolt, the yoke, canon or ear, mouth, sound-bow, shoulder, and barrel.

When a bell is to be constructed, the weight or key-note is given, and the diameter and sound-bow are calculated. By the following rules all the various data may be determined.*

1. The weight of a bell is found by multiplying together the square of the diameter at the mouth in inches by the thickness of the sound-bow in inches and by .25. *Example:* Required the weight of a bell 60 inches in diameter, sound-bow 4.8 inches thick. $.25 \times 60^2 \times 4.8 = 4{,}320$ lbs. weight.

2. The diameter of a bell may be determined by dividing 4 times the weight in avoirdupois pounds by a coefficient expressing the relative thickness of the sound-bow to the diameter of the bell, which varies from .07 to .08, and extracting the cube-root. In peals of bells the sound-bow is generally put .08 times the diameter at mouth in inches for the treble, and .07 times for the tenor; for the intermediate bells in the peal, proportions lying between these for the respective sound-bows. *Example:* A bell of 2,636.4 lbs. is to be constructed with a sharp note, putting for the sound-bow .075. What is the diameter? $\sqrt[3]{\frac{4 \times 2{,}636.4}{.075}} = 52$ inches.

* From Spon's "Dictionary of Engineering."

3. To find the key-note, the diameter and thickness at sound-bow being given, multiply the sound-bow thickness by 58,000 and divide by the square of the diameter. The answer is in vibrations per second. *Example:* The key-note of a bell, with diameter 44 inches and sound-bow 3.52 inches thick: $58{,}000 \times \frac{3.52}{44^2} = 105.45$ vibrations per second, which corresponds nearly to the note A in the first octave below zero in the bars. The second octave below this would be 53.8 vibrations, and the third 26.90 vibrations.

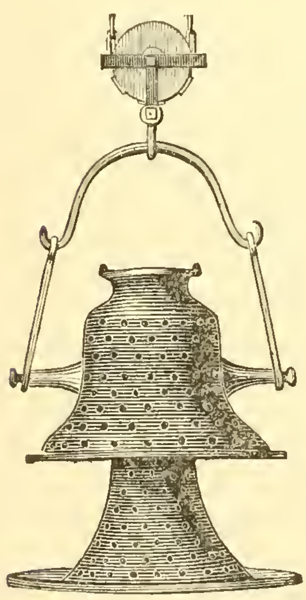
4. The key-note and weight given, to find diameter divide the weight by the number of vibrations per second corresponding to the note, extract fourth root and multiply by 21.947. *Example:* Weight 6,561 lbs., key-note C in first octave below zero (64 vibrations). Then $21{,}947 \times \sqrt[4]{\frac{6{,}561}{64}} = 69.84$ inches.

5. Given the diameter and number of vibrations, to find the thickness of sound-bow multiply the square of the diameter by the vibration number and divide by 58,000. *Example:* Taking the figures of last example, $\frac{64 \times (69.84)^2}{58{,}000} = 5.38$ inches.

After calculation by the above formulas is concluded, the diameter of the bell at the mouth is divided into 10 square parts, called strokes, which then is the scale and measurement for the construction. Shrinkage is allowed at three-sixteenths of an inch to the foot. The section of the bell is usually laid out on a piece of board, which is then cut out and used for turning up the mould of the bell. Bells can be made almost in any form without seriously affecting the quality of tone; but the thickness of metal should always be in proportion to the square of the diameter taken at the centre of the metal. Several methods are employed for tracing bells. The one mostly used in France gives 15 thicknesses of the bow to the diameter, $7\frac{1}{2}$ to the diameter of the crown, 12 to the line forming the lower ridge of the bell and the base of the crown, and, finally, 32 to the great radius serving to trace the profile of the bell proper. The weight of the clapper should be from one-fortieth to one-fiftieth the weight of the bell.

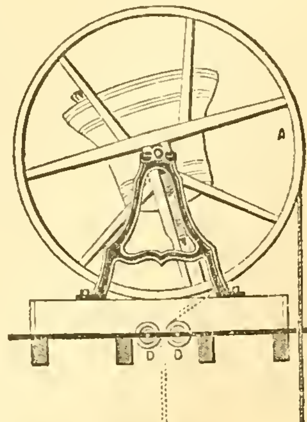
*Casting Bells.*—The method of casting bells employed by Messrs. Meneely & Co., of Troy, N. Y., is shown in Fig. 309. In the upper case is made the outside mould of the bell, and upon the lower the inside mould. The material of the mould is a porous clay loam, put on from one to three inches in thickness, according to the size of the bell. The proper shape and finish is given to it by means of sweep-boards, cut respectively to the shape of the outer and inner vertical sections of the proposed bell, and which are made to revolve upon a centre representing that of the bell, fixed in the centre of the cases. Before the clay is put on the inner mould case it is wrapped with straw-rope, which, becoming charred with the heat when the bell is poured, permits it to shrink in cooling without straining. The perforations in the cases serve to make the clay more firmly adhere to them, and also to vent the mould. In the old method of casting, the moulds, being made entirely of clay, were necessarily packed about with sand in order to withstand the pressure of the metal, and the confined air within not entirely escaping would cause a porous casting, or, being converted into an inflammable gas, would take fire and explode. In using these cases, the bell is poured above-ground, and whatever gas may be generated in the mould permeates through the clay and burns off at each hole in a pale jet of flame, thus being entirely removed.

309.



*Hanging Bells.*—Bells are suspended in yokes, journaled in frames, and are swung by means of a wheel secured to the yoke, the bell-rope leading from the wheel-rim (Fig. 310). The manner of attaching the rope is shown in the accompanying cut, it being fastened to the wheel at *A*, and, if the bell is of medium weight, it passes down directly under the centre of the wheel through the sheaves at *D*. With this arrangement the bell may be thrown over, as it will be more or less, and the connection of the rope with the wheel will not be deranged. If the weight of the bell is such that with the bend in the rope at *D* the labor of ringing is too great, then it should be run down in a straight line through the floor, in which case no sheaves are necessary. In order to prevent the bell being thrown over, it is well to provide a stop on the wheel. The rope should not be larger than is necessary, as its inflexibility and weight encumber the free spring of the bell. As it is impracticable, however, to ring a bell of considerable weight by a small rope on account of the difficulty of grasping it firmly in the hand, we here give the sizes of ropes suitable for bells of different weights:

310.




| | | | |
|---|---|---|---|
| For bells of less than | 500 lbs., | $\frac{1}{2}$ | inch diameter. |
| " from 500 to | 800 " | $\frac{5}{8}$ | " |
| " from 900 to | 1,500 " | $\frac{3}{4}$ | " |
| " above | 1,500 " | 1 | " |

*Chimes* are numbers of bells attuned to each other in diatonic succession. A peal consists of three or more bells in harmonic succession, which may be rung successively or simultaneously, but will not admit of a tune being played upon them. Thus, a set embracing the eight notes of the gamut will constitute a chime, while one upon the first, third, fifth, and eighth

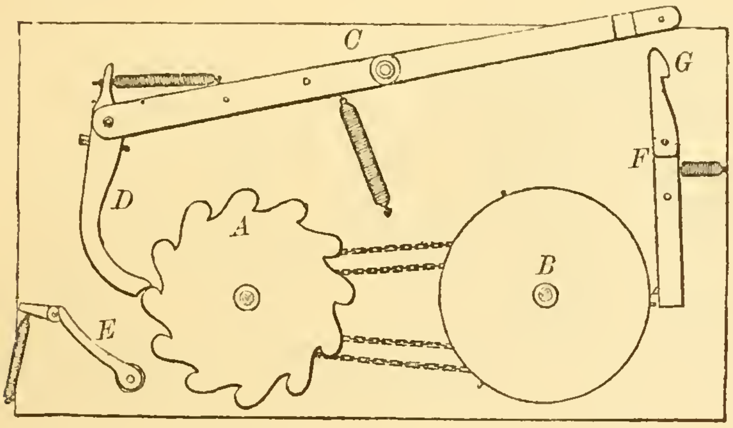
of the scale would be a peal. The usual number of bells in a chime is nine, embracing the seven notes of the scale the octave and a flat seventh. Bells are caused to sound either by swinging them, and so causing the clappers to strike them, or by the aid of hammers of various weights, according to the size of the bell, caused to rise and suffered to fall on the bell. Peals are rung by hand, the bells being swung; clocks always strike the bell with a hammer, the bell being at rest. The hammer is raised by a wire, which pulls down the hammer-tail, the wire being worked by a lever, the end of which is caught by a cam on a revolving barrel in the clock below. It is obvious that, if a number of bells are all fitted with hammers, and the number of cams is sufficiently great, and the cams are properly arranged, a tune can be played by a mere multiplication of the device by which a clock is made to strike the hours on a single bell.

*The Carillon Machine* embodies this arrangement—only, instead of cams, a number of short pins are set in a revolving barrel, and these pins catch the toes of levers connected by wires with the hammer-tails in the bell-chamber above. The pins are set or pricked in precisely the same way as the little points in the barrel of a musical box. The hammer, after it has fallen, can only be lifted by the rotation of the barrel; and, as the time of dropping the hammer depends entirely on the rotation of the barrel, it is obvious that the barrel can only revolve at a slow speed, and much time is lost in lifting the hammer. The result is that a rapid musical passage cannot possibly be performed. Another result is that, when the small bells, the high notes, come to be played, the barrel meets with less resistance, and revolves faster than when it has to deal with the deep notes and large bells. It follows that the air is played out of time.

These difficulties are overcome by the invention illustrated in Fig. 311. It is intended to show the gear for working one hammer. It must be multiplied in proportion to the number of hammers, but the parts are all repetitions of each other. It will be understood that this engraving does not show details, but simply illustrates a principle.

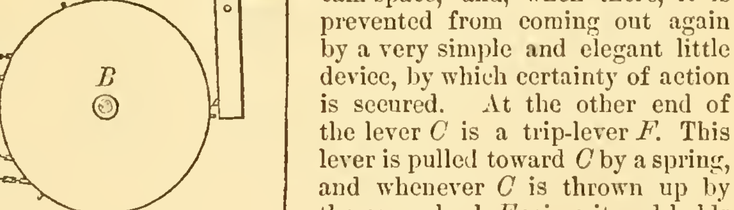
The musical barrel *B* is set with pins in the usual way. *A* is a cam-wheel of very peculiar construction, operating a lever *C* by what is, to all intents and purposes, a new mechanical motion, the peculiarity of which is that, however fast the cam-wheel revolves, the tripping of the lever is avoided. In all cases the outer end must be lifted to its full height before the swinging place *D* quits the cam. The little spring-roller *E* directs the tail *D* of the lever into the cam-space, and, when there, it is prevented from coming out again by a very simple and elegant little device, by which certainty of action is secured. At the other end of the lever *C* is a trip-lever *F*. This lever is pulled toward *C* by a spring, and whenever *C* is thrown up by the cam-wheel, *F* seizes it and holds it up; but the wire to the bell-hammer in the tower above it is secured to the eye *G*, so that, when *D* is lifted, the eye *G* being pulled down, the hammer is lifted. The pins in the musical barrel *B* come against a step in *F*; and as they pass by they push *F* outward and release *C*, which immediately drops, and with it the hammer, so that the instant a pin passes the step *F* a note is sounded. But the moment *D* drops, it engages with *A*, which last revolves at a very high speed, and *D* is incontinently flung up again, and the hammer raised, and raised it remains until the next pin *B* passes the step on *F*, and again a note is struck. It will be seen, therefore, that, if we may use the phrase, *B* has nothing to do but let off traps set continually by *A*; and, so long as *A* sets the traps fast enough, *B* will let them off in correct time. But *A* revolves so fast and acts so powerfully that it makes nothing of even a 3-cwt. hammer, much less the little ones; and thus is obtained a facility of execution heretofore unknown in carillon machinery. The machine illustrated has been put up in the parish church at Shoreditch, London, by Messrs. Gillett & Bland. It plays 14 tunes on 12 bells—one of the finest peals in London, the tenor weighing no less than 34 cwt. Two barrels are used, which can be changed by hand. The peal ranges from CC to G. There are 24 levers, two to each bell, to insure facility in playing rapid passages without driving the cam-barrel too fast. The motive power is supplied by a weight of 9 cwt., allowed to fall 72 feet, and wound up every 24 hours.

311.




BELTS.—In the ordinary acceptance of the term, belts are endless strips of leather, rubber, or other flexible material, stretched over pulleys for the purpose of transmitting power from one pulley, called the driver, to the other, or driven, pulley. Ropes and chains are also used in a similar manner, forming rope, or chain, belting. When chains are employed, the pulleys over which they pass commonly have depressions or projections on the rims, which engage with the links of the chains and prevent slipping. This arrangement forms a positive gearing, and it is to be distinguished from ordi-

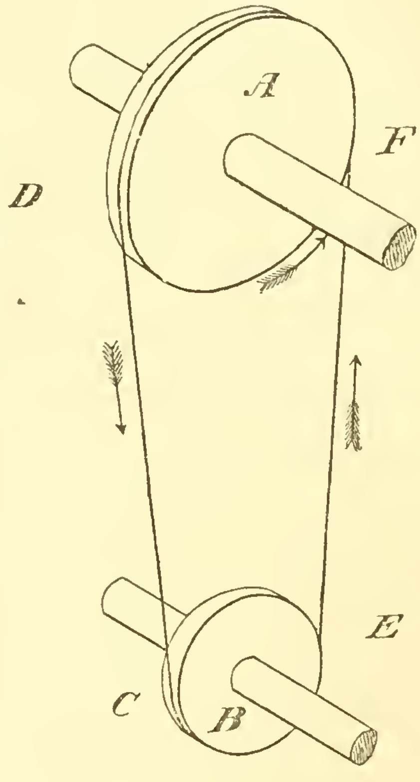
312.



nary belting, in which power is transmitted by reason of the friction between the belt and the face of the pulley. A convenient form of chain-belt, made by the Ewart Manufacturing Company, is represented in Fig. 312. It is composed of detachable links, so that its length can readily be changed.

Fig. 313 is a sketch of the ordinary belt-connection, *A* being the driving pulley, revolving in the direction of the arrow, and connected to the driven pulley *B* by the endless band *D C E F*. The portion of the belt, *E F*, running away from the driven pulley, is the driving part of the belt, and the portion, *D C*, running toward the driven pulley, is the slack part of the belt. These are the names ordinarily given to the two parts of the belt, for reasons that are easily explained. Suppose the belt is stretched over the pulleys with a certain tension—for example, 40 lbs. for each inch of width. When the pulleys are at rest, all parts of the belt will have this tension of 40 lbs. per inch, but if motion ensues and power is transmitted, it is obvious that one part of the belt must have its tension increased. *For example:* Suppose that the belt, when strained as described above, requires a force of 26 lbs. per inch of width to slip it on the driven pulley, then the tension of the driving part, *E F*, will evidently be 40 + 26 = 66, and the tension of the slack part, *D C*, 40 — 26 = 16, lbs. per inch of width, if the belt is driving up to its full capacity. As the different portions of the belt become alternately tight and slack, in passing from one side of the driven pulley to the other, and the belt is elastic, it is evident that, even if there is no slip such as occurs when a belt is overtaxed, there will be, under all circumstances, a *creep*, due to the elasticity, which will, of course, vary with different belts and different tensions. As explained by Prof. Osborne Reynolds: "The strap comes on to *A* tight and stretched, and leaves it unstretched. It has, therefore, contracted while on the pulley. This contraction takes place gradually from the point at which it comes on to that at which it leaves, and the result is that the strap is continually slipping over the pulley to the point at which it first comes on. In the same way with *B:* the strap comes on unstretched and leaves it stretched, and has expanded while on the wheel, which expansion takes place gradually from the point at which the strap comes on until it leaves." * Hence, the velocity-ratio of two pulleys connected by a belt will not be constant under all circumstances, as the belt does not form a positive connection. In ordinary practice, the loss caused by the creep is very slight, but with highly elastic belts, tightly stretched, it may be considerable; and in any case where absolute uniformity of velocity-ratio is required, belts cannot be used. For driving most kinds of machinery, however, the facts that the belt is elastic and yielding, and that it will slip if overstrained, render it one of the best appliances for transmitting power without producing injurious shocks.

313.




The ordinary materials used for belts are leather and rubber. Experiment shows that a rubber belt will usually transmit at least 25 per cent. more power before slipping than one of leather under the same circumstances—and in many cases the rubber belt has other decided advantages. For instance, it is difficult to make a very wide leather belt of the same quality throughout its entire width, because the hides of which it is composed are usually thicker and of firmer texture in the centre than on the sides. By making a careful selection of hides, and using only selected portions of them, it is possible to construct a wide leather belt of practically uniform quality throughout; but generally, in the case of a very wide belt, one of rubber will run more truly and wear more satisfactorily than a leather one. It may be further remarked, that in damp and exposed situations, in which leather belts would soon become worthless, rubber ones can frequently be used with success. The rubber belt is, however, of more limited application than the other. The weak points of a rubber belt are its edges, which should not come in contact with anything; so that, when crossed or shifting belts are used, it is not well to make them of rubber.

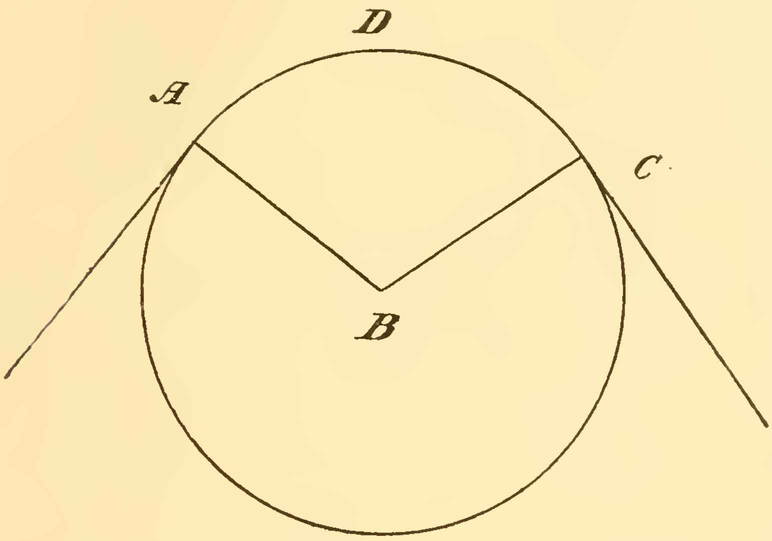
The principles upon which the transmission of power by belts depends, have been carefully investigated, both by analysis and experiment, and many valuable experimental data have been compiled. Experiments on the amount of power that can be transmitted by a belt of given size show many discrepancies, which seem to be due to the fact that belts of different quality were experimented upon, and it is pretty well settled that, while rules can be constructed that will show what power a good belt *may* transmit under given conditions, they cannot be implicitly relied upon to show how much power a particular belt *does* transmit. A question of this kind can only be answered by experiment, although the rules may frequently enable an experienced person to predict the result with considerable accuracy. Rules giving results that agree with good practice will be found in another part of this article, but before explaining their use it may be well to devote a little space to the consideration of some other points connected with the subject.

It is proved, by both analysis and experiment, that the friction between a belt and a pulley varies with the tension, is independent of the area of the surface of contact, and increases as the angle or arc of contact increases. To illustrate, suppose, in Fig. 314, that a belt is in contact with a pulley for the distance *A D C*, making the angle of contact (or angle between radii drawn to extremities of

* *The Engineer*, xxxviii., 396.

arc of contact) $A\,B\,C$, then, if the tension of the belt is unchanged, the friction is the same whether the pulley is 2 feet or 10 feet in diameter, and if the speed of the belt remains the same, the amount of power transmitted will be the same for either case. This may seem contrary to the experience of many—for it is not an uncommon thing to replace pulleys by larger ones, having the same relative dimensions, the change resulting in a great increase of power, and as the *angle* of contact is not altered by the changes, while the area of contact is increased, it seems at first sight to be a fair conclusion that the gain in power is caused by the increased area. So obvious, indeed, does this appear to many, that numerous rules have been published, in which the transmitting power is made to depend upon the *area* of contact, and is entirely independent of the *arc*. A little reflection will show, however, that the increase of power, in a change such as described above, is caused by something very different from an increase in area of contact. The power transmitted by a belt depends, first, upon the difference of tension of the two parts of the belt, or force that it can transmit; and, second, upon the velocity with which this force is transmitted. Now, in changing from one pair of pulleys to another, in which the diameters are doubled, the same force may be transmitted in either, but if the revolutions per minute are unchanged, the velocity with which the force is transmitted will be twice as great in the second case as in the first, so that the power will be doubled. Both theory and experiment fully confirm the statement that the power transmitted, other things being equal, is entirely independent of the area of contact of the belt with the pulley. The only limitation is in the case of very small pulleys and stiff belts, where a considerable proportion of the power is expended in bending the belts; but, ordinarily, the angle of contact determines the power that a belt will transmit at a given tension and velocity. A belt that will not do the work required of it, however tightly it may be stretched, on account of the small angle of contact with the driven pulley, can sometimes be rendered sufficiently powerful when less tightly strained, by the use of a binder or tightener, close to the driven pulley, which bends the belt through a larger angle of contact. Frequently, however, in the case of a belt passing over two pulleys of greatly disproportionate size, very close together, the use of a tightener occasions loss of power by the abrupt bends which it induces in the belt, and the requisite tension may be better obtained by crossing the belt, since in the case of a crossed belt the angle of contact is the same for each pulley, whatever their relative sizes.

314.




If a pulley has a high side, as it is called, or a greater diameter in one part than another, the belt tends to run toward the high part, and advantage is taken of this fact, in practice, to keep the belt running straight by making the pulley with a curved face, having the greatest diameter in the centre. Very frequently this crowning of the pulley-face is overdone, the result being that the belt does not touch the pulley over the whole of its width. Where a belt has been running for a little time, an examination will show whether it touches all over, and, if it does not, the high part of the pulley should be reduced. Flat-faced pulleys can be successfully run if first-class belts are used, and the shafts are kept in line—crowning a pulley being simply a device to counteract the bad effects arising from the use of a crooked belt or imperfectly adjusted driving-gear. The tendency of a belt to run to one side or the other if a slight side-pressure is brought to bear, finds its application in the case of shifting belts, which at times are employed to drive machinery, and are occasionally shifted to loose pulleys, it only being necessary to apply the side-pressure near the pulley where the shift is to be made, and on the part of the belt that is approaching the pulley.

Experiments show that a leather belt will transmit more power, and wear more satisfactorily, if it is run with the finished side next the pulleys, the reason, apparently, being that the belt has greater friction on account of the more perfect contact. There are various special preparations that are recommended for application to leather belts, to render them pliable and preserve them, but the weight of testimony seems to favor the occasional application of either neat's-foot or castor oil. Belts are connected by hooks or lacing, and occasionally they are riveted together at the ends. The latter plan is generally the best, if the belt is first run a sufficient time to stretch it thoroughly.

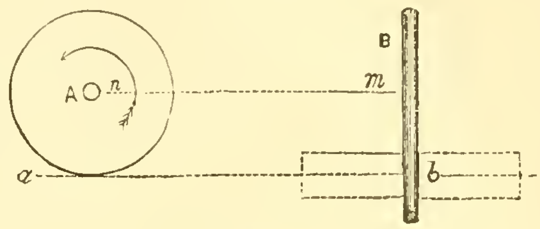
When motion is produced by means of a belt-connection, the velocity-ratio of the pulleys depends on their relative diameters and the thickness of the belt. The effective diameter of a pulley is its diameter increased by the thickness of the belt, and this should be used in calculations for velocity-ratio.

*To find the diameter of a pulley for a required speed, the diameter and speed of the other pulley being known.* Divide the given speed by the required speed, and multiply the quotient by the given diameter.

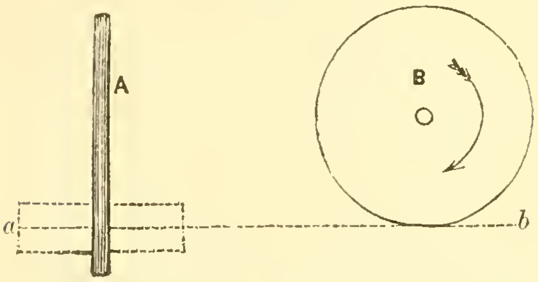
*Example:* One pulley has a diameter of 5 feet, and makes 100 revolutions a minute. What should be the diameter of the other pulley to make 130 revolutions a minute? $\frac{100}{130} \times 5 = 3.84 +$ feet.

In transmitting motion by a belt, it is sometimes required that the two pulleys shall revolve in different planes. It is only necessary that a belt, to maintain its position, should have its advancing side in the plane of rotation of that section of the pulley on which it is required to remain, without regard to the retiring side. On this principle, motion may be conveyed by belts to shafts oblique to each other. Let $A$ and $B$ (Fig. 315) be two shafts at right angles to each other, $A$ vertical, $B$ horizontal, so that the line run perpendicular to the direction of one axis is also perpendicular to the other, and let it be required to connect them by pulleys and a belt, that their direction of motion may be as shown by the arrows: their velocities will be as 3 of $A$ to 2 of $B$. On $A$ describe the circumference of the pulley proposed on that shaft; to this circumference draw a tangent $a\ b$ parallel to $m\ n$: this line will be the projection of the edge of the belt as it leaves $A$, and the centre of the belt as it approaches $B$; consequently, lay off the pulley $b$ on each side of this line, and of a diameter proportional to the velocity required. To fix the position of the pulley on $A$, let Fig. 316 be another view taken at right angles to Fig. 315, and let the axis $B$ have

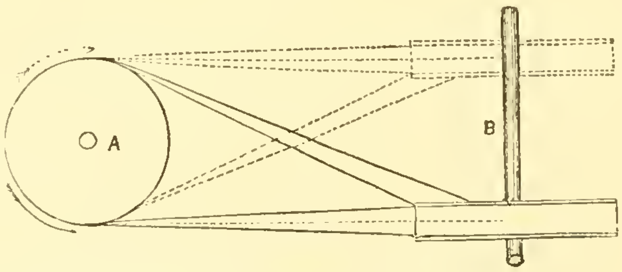
315.




316.



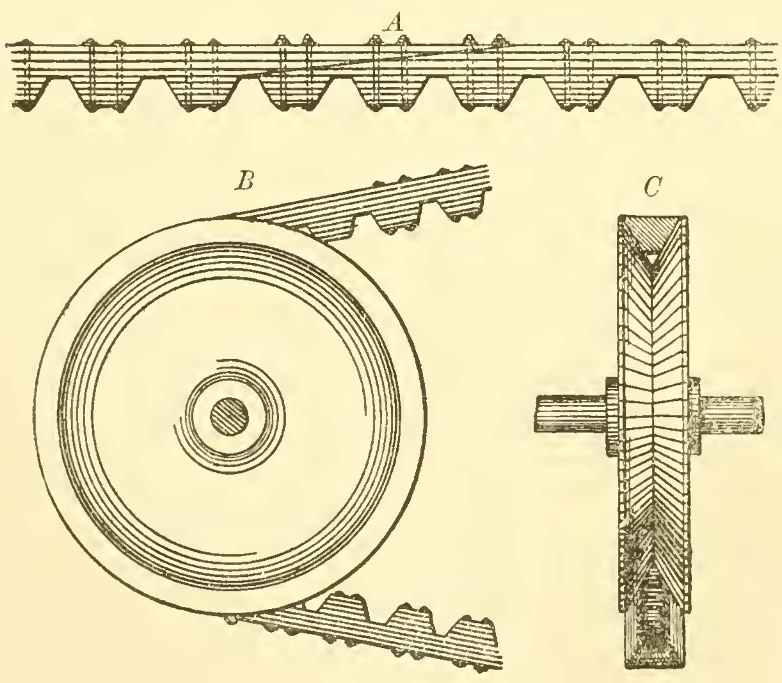

317.




the direction of motion indicated by the arrow; then the circle of the pulley being described, and a tangent $a\ b$ drawn to it perpendicular to the axis $B$ as before determined, the position of the pulley on the shaft $A$ is established.

The positions of the two pulleys are thus fixed in such a way that the belt is always delivered by the pulley it is receding from into the plane of rotation of the pulley toward which it is approaching. If the motion be reversed, the belt will run off; thus (Fig. 317) if the motion of the shaft $A$ is reversed, the pulley $B$ must be placed in the position shown by the dotted lines. In order to obviate this, round belts running in grooved pulleys are frequently employed in such cases where the power transmitted is small, and a peculiar form of angular belting working in pulleys having V-shaped faces is very often used for the transmission of considerable amounts of power. This belting is illustrated in Fig. 318, $A$ showing the method of construction and connection of the ends, and $B$ and $C$ the application to pulleys.

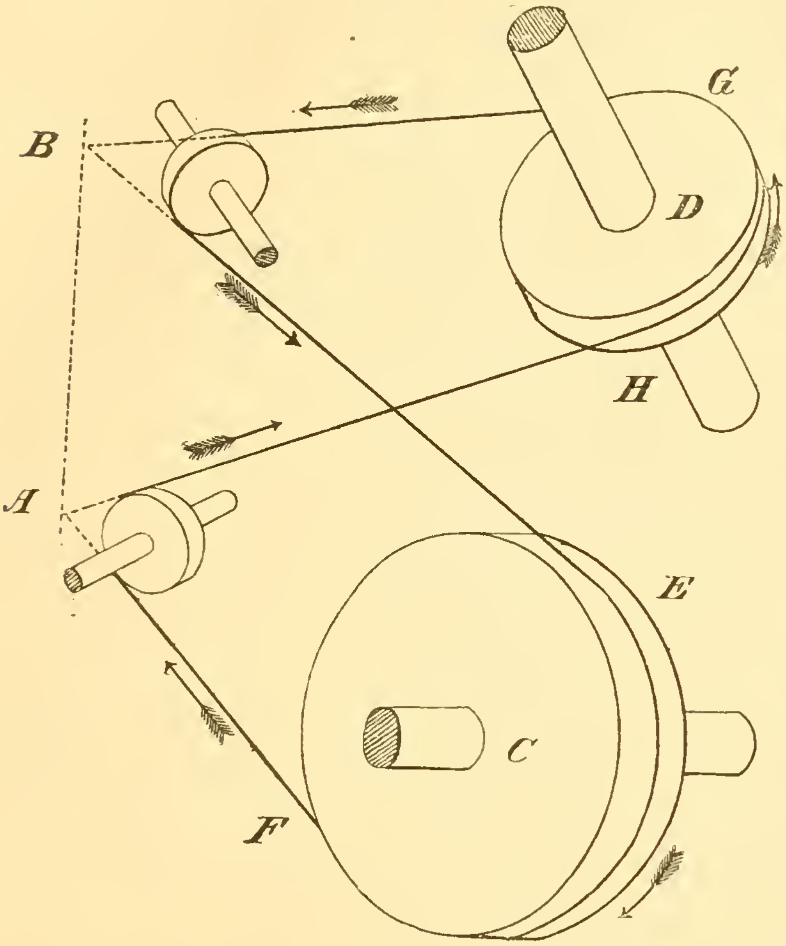
318.



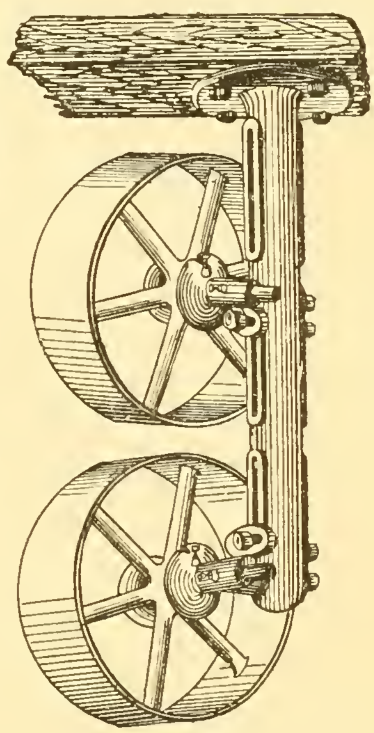

It is not an essential condition that the shafts should be at right angles to each other to have motion transferred by a belt. They may be placed at any angle to each other provided the shafts lie in parallel planes, so that the perpendicular drawn to one axis is perpendicular to the other. If otherwise, recourse must be had to guide-pulleys, as illustrated in Fig. 319, which shows the manner of finding the positions of the guide-pulleys. If planes are passed through the centres of the two pulleys $C$ and $D$, at right angles to the shafts, they will intersect in a line $A\ B$. Assume any points, $A$ and $B$, in this line, and in the plane of the pulley $C$ draw the tangents $B\ E$, $A\ F$, and in the plane of the pulley $D$ the tangents $A\ H$, $B\ G$. These tangents represent the path of the belt in passing from pulley $C$ to pulley $D$, and to keep it in this path it will only be necessary to introduce two guide-pulleys, one at $A$, in the plane $H\ A\ F$, and the other at $B$, in the plane $E\ B\ G$.

In Fig. 320 is shown a "binder frame," as constructed by William Sellers & Co., in which the guide-pulleys can easily be adjusted so as to revolve in the required planes.

319.




320.



Problems relating to the length of belts and amount of power transmitted are of frequent occurrence. Explanations of the manner of solving the most important examples are appended. The operations will in general be greatly facilitated by using the following table:

*Table for determining Length of Belts and Power transmitted.*

| ARGUMENT. | Factors for Length of Belt, to be multiplied by distance between centres of pulleys. | | | ARC OF CONTACT OF BELT WITH PULLEY. | | | | | | Horse-Power that can be transmitted by a single Leather Belt, one inch wide, at a Velocity of 1,000 Feet per Minute. | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Crossed Belt. | Open Belt. | | Both Pulleys, Crossed Belt, and Large Pulley, Open Belt. | | | Small Pulley, Open Belt. | | | | |
| | | For Difference of Radii. | For Sum of Radii. | Fraction of Circumference. | Degrees in Arc. | Length for a Radius of 1. | Fraction of Circumference. | Degrees in Arc. | Length for a Radius of 1. | For Greater Arc of Contact. | For Smaller Arc of Contact. |
| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
| 0. | 2.000 | 2.000 | 0. | .500 | 180. | 3.142 | .500 | 180. | 3.142 | 1.485 | 1.485 |
| .01 | 2.032 | 2.001 | .031 | .503 | 181.2 | 3.160 | .497 | 178.8 | 3.123 | 1.490 | 1.480 |
| .02 | 2.064 | 2.001 | .063 | .507 | 182.3 | 3.186 | .493 | 177.7 | 3.098 | 1.494 | 1.476 |
| .03 | 2.095 | 2.001 | .094 | .510 | 183.5 | 3.204 | .490 | 176.5 | 3.079 | 1.499 | 1.471 |
| .04 | 2.127 | 2.001 | .126 | .513 | 184.6 | 3.223 | .487 | 175.4 | 3.060 | 1.503 | 1.467 |
| .05 | 2.159 | 2.002 | .157 | .516 | 185.8 | 3.242 | .484 | 174.2 | 3.041 | 1.508 | 1.462 |
| .06 | 2.191 | 2.103 | .188 | .519 | 186.8 | 3.261 | .481 | 173.2 | 3.022 | 1.512 | 1.457 |
| .07 | 2.235 | 2.005 | .220 | .522 | 188. | 3.280 | .478 | 172. | 3.003 | 1.516 | 1.452 |
| .08 | 2.258 | 2.007 | .251 | .525 | 189.2 | 3.299 | .475 | 170.8 | 2.985 | 1.520 | 1.447 |
| .09 | 2.291 | 2.008 | .283 | .529 | 190.3 | 3.324 | .471 | 169.7 | 2.959 | 1.524 | 1.443 |
| .10 | 2.324 | 2.010 | .314 | .532 | 191.5 | 3.343 | .468 | 168.5 | 2.941 | 1.528 | 1.438 |
| .11 | 2.358 | 2.012 | .346 | .535 | 192.6 | 3.362 | .465 | 167.4 | 2.922 | 1.532 | 1.433 |
| .12 | 2.392 | 2.015 | .377 | .538 | 193.8 | 3 380 | .462 | 166.2 | 2.903 | 1.537 | 1.428 |
| .13 | 2.425 | 2.017 | .408 | .542 | 195. | 3.405 | .458 | 165. | 2.878 | 1.541 | 1.423 |
| .14 | 2.459 | 2.019 | .440 | .545 | 196.1 | 3.424 | .455 | 163.9 | 2.859 | 1.545 | 1.418 |
| .15 | 2.493 | 2.022 | .471 | .548 | 197.3 | 3.443 | .452 | 162.7 | 2.840 | 1.550 | 1.413 |
| .16 | 2.528 | 2.026 | .502 | .551 | 198.4 | 3.462 | .449 | 161.6 | 2.821 | 1.554 | 1.408 |
| .17 | 2.563 | 2.029 | .534 | .554 | 199.6 | 3.481 | .446 | 160.4 | 2.802 | 1.558 | 1.402 |
| .18 | 2.598 | 2.032 | .566 | .558 | 200.8 | 3.506 | .442 | 159.2 | 2.777 | 1.561 | 1.396 |
| .19 | 2.634 | 2.037 | .597 | .561 | 202. | 3.525 | .439 | 158. | 2 758 | 1.565 | 1.391 |
| .20 | 2.669 | 2.041 | .628 | .564 | 203.1 | 3.544 | .436 | 156.9 | 2.739 | 1.568 | 1.386 |
| .21 | 2.705 | 2.045 | .660 | .567 | 204.2 | 3.563 | .433 | 155.8 | 2.721 | 1.572 | 1.381 |
| .22 | 2.740 | 2.049 | .691 | .571 | 205.4 | 3.588 | .429 | 154.6 | 2.695 | 1.575 | 1.375 |
| .23 | 2.775 | 2.053 | .722 | .574 | 206.6 | 3.607 | .426 | 153.4 | 2.677 | 1.579 | 1.368 |
| .24 | 2.812 | 2.058 | .754 | .577 | 207.7 | 3.625 | .423 | 152.3 | 2.658 | 1.583 | 1.362 |

*Table for determining Length of Belts and Power transmitted*—(Continued).

| ARGUMENT. | Factors for Length of Belt, to be multiplied by distance between centres of pulleys. | | | ARC OF CONTACT OF BELT WITH PULLEY. | | | | | | Horse-Power that can be transmitted by a single Leather Belt, one inch wide, at a Velocity of 1,000 Feet per Minute. | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Crossed Belt. | Open Belt. | | Both Pulleys, Crossed Belt, and Large Pulley, Open Belt. | | | Small Pulley, Open Belt. | | | | |
| | | For Difference of Radii. | For Sum of Radii. | Fraction of Circumference. | Degrees in Arc. | Length for a Radius of 1. | Fraction of Circumference. | Degrees in Arc. | Length for a Radius of 1. | For Greater Arc of Contact. | For Smaller Arc of Contact. |
| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
| .25 | 2.849 | 2.063 | .786 | .580 | 208.9 | 3.644 | .420 | 151.1 | 2.639 | 1.588 | 1.356 |
| .26 | 2.885 | 2.068 | .817 | .583 | 210.1 | 3.663 | .417 | 149.9 | 2.620 | 1.592 | 1.351 |
| .27 | 2.922 | 2.074 | .848 | .587 | 211.3 | 3.688 | .413 | 148.7 | 2.595 | 1.596 | 1.345 |
| .28 | 2.959 | 2.079 | .880 | .590 | 212.5 | 3.707 | .410 | 147.5 | 2.576 | 1.600 | 1.340 |
| .29 | 2.996 | 2.085 | .911 | .594 | 213.7 | 3.732 | .406 | 146.3 | 2.551 | 1.603 | 1.334 |
| .30 | 3.034 | 2.091 | .943 | .597 | 214.9 | 3.751 | .403 | 145.1 | 2.532 | 1.607 | 1.328 |
| .31 | 3.071 | 2.097 | .974 | .600 | 216.1 | 3.770 | .400 | 143.9 | 2.513 | 1.610 | 1.322 |
| .32 | 3.109 | 2.104 | 1.005 | .604 | 217.3 | 3.795 | .396 | 142.7 | 2.488 | 1.614 | 1.316 |
| .33 | 3.147 | 2.110 | 1.037 | .607 | 218.5 | 3.814 | .393 | 141.5 | 2.469 | 1.618 | 1.309 |
| .34 | 3.185 | 2.117 | 1.068 | .610 | 219.7 | 3.833 | .390 | 140.3 | 2.450 | 1.621 | 1.303 |
| .35 | 3.224 | 2.125 | 1.099 | .614 | 220.9 | 3.858 | .386 | 139.1 | 2.425 | 1.625 | 1.296 |
| .36 | 3.262 | 2.131 | 1.131 | .617 | 222.2 | 3.877 | .383 | 137.8 | 2.406 | 1.628 | 1.289 |
| .37 | 3.301 | 2.138 | 1.163 | .621 | 223.4 | 3.902 | .379 | 136.6 | 2.381 | 1.632 | 1.282 |
| .38 | 3.340 | 2.146 | 1.194 | .624 | 224.6 | 3.921 | .376 | 135.4 | 2.362 | 1.635 | 1.276 |
| .39 | 3.380 | 2.155 | 1.225 | .627 | 225.8 | 3.940 | .373 | 134.2 | 2.344 | 1.638 | 1.270 |
| .40 | 3.419 | 2.162 | 1.257 | .631 | 227.1 | 3.965 | .369 | 132.9 | 2.318 | 1.642 | 1.263 |
| .41 | 3.459 | 2.170 | 1.289 | .635 | 228.4 | 3.990 | .365 | 131.6 | 2.293 | 1.646 | 1.256 |
| .42 | 3.499 | 2.179 | 1.320 | .638 | 229.7 | 4.009 | .362 | 130.3 | 2.275 | 1.649 | 1.248 |
| .43 | 3.540 | 2.189 | 1.351 | .642 | 231. | 4.034 | .358 | 129. | 2.249 | 1.653 | 1.240 |
| .44 | 3.580 | 2.197 | 1.383 | .645 | 232.2 | 4.053 | .355 | 127.8 | 2.231 | 1.656 | 1.233 |
| .45 | 3.620 | 2.206 | 1.414 | .649 | 233.5 | 4.078 | .351 | 126.5 | 2.205 | 1.660 | 1.226 |
| .46 | 3.661 | 2.216 | 1.445 | .652 | 234.8 | 4.097 | .348 | 125.2 | 2.187 | 1.663 | 1.218 |
| .47 | 3.702 | 2.225 | 1.477 | .656 | 236.1 | 4.122 | .344 | 123.9 | 2.161 | 1.667 | 1.210 |
| .48 | 3.743 | 2.235 | 1.508 | .660 | 237.4 | 4.147 | .340 | 122.6 | 2.136 | 1.670 | 1.203 |
| .49 | 3.785 | 2.245 | 1.540 | .663 | 238.7 | 4.166 | .337 | 221.3 | 2.117 | 1.674 | 1.195 |
| .50 | 3.827 | 2.256 | 1.571 | .667 | 240. | 4.191 | .333 | 120. | 2.092 | 1.677 | 1.187 |
| .51 | 3.868 | 2.266 | 1.602 | .670 | 241.3 | 4.210 | .330 | 118.7 | 2.073 | 1.680 | 1.179 |
| .52 | 3.911 | 2.277 | 1.634 | .674 | 242.6 | 4.235 | .326 | 117.4 | 2.048 | 1.683 | 1.171 |
| .53 | 3.954 | 2.289 | 1.665 | .678 | 244. | 4.260 | .322 | 116. | 2.023 | 1.687 | 1.162 |
| .54 | 3.996 | 2.299 | 1.697 | .682 | 245.4 | 4.285 | .318 | 114.6 | 1.998 | 1.690 | 1.153 |
| .55 | 4.039 | 2.311 | 1.728 | .685 | 246.7 | 4.304 | .315 | 113.3 | 1.979 | 1.693 | 1.145 |
| .56 | 4.082 | 2.323 | 1.759 | .689 | 248.1 | 4.329 | .311 | 111.9 | 1.954 | 1.696 | 1.136 |
| .57 | 4.126 | 2.335 | 1.791 | .693 | 249.5 | 4.354 | .307 | 110.5 | 1.929 | 1.700 | 1.126 |
| .58 | 4.169 | 2.347 | 1.822 | .697 | 250.9 | 4.379 | .303 | 109.1 | 1.904 | 1.703 | 1.117 |
| .59 | 4.213 | 2.360 | 1.853 | .701 | 252.3 | 4.405 | .299 | 107.7 | 1.879 | 1.707 | 1.108 |
| .60 | 4.257 | 2.372 | 1.885 | .705 | 253.8 | 4.430 | .295 | 106.2 | 1.854 | 1.710 | 1.098 |
| .61 | 4.303 | 2.386 | 1.917 | .709 | 255.2 | 4.455 | .291 | 104.8 | 1.828 | 1.713 | 1.089 |
| .62 | 4.347 | 2.399 | 1.948 | .713 | 256.7 | 4.480 | .287 | 103.3 | 1.803 | 1.717 | 1.078 |
| .63 | 4.392 | 2.412 | 1.980 | .717 | 258.1 | 4.505 | .283 | 101.9 | 1.778 | 1.720 | 1.068 |
| .64 | 4.437 | 2.426 | 2.011 | .721 | 259.6 | 4.530 | .279 | 100.4 | 1.753 | 1.723 | 1.058 |
| .65 | 4.482 | 2.440 | 2.042 | .725 | 261.1 | 4.555 | .275 | 98.9 | 1.728 | 1.726 | 1.047 |
| .66 | 4.529 | 2.455 | 2.074 | .729 | 262.6 | 4.580 | .271 | 97.4 | 1.703 | 1.730 | 1.036 |
| .67 | 4.574 | 2.469 | 2.105 | .733 | 264.1 | 4.606 | .267 | 95.9 | 1.678 | 1.733 | 1.025 |
| .68 | 4.621 | 2.484 | 2.137 | .738 | 265.7 | 4.637 | .262 | 94.3 | 1.646 | 1.736 | 1.013 |
| .69 | 4.667 | 2.499 | 2.168 | .742 | 267.2 | 4.662 | .258 | 92.8 | 1.621 | 1.739 | 1.002 |
| .70 | 4.714 | 2.515 | 2.199 | .747 | 268.8 | 4.694 | .253 | 91.2 | 1.590 | 1.743 | .990 |
| .71 | 4.762 | 2.531 | 2.231 | .751 | 270.4 | 4.719 | .249 | 89.6 | 1.565 | 1.746 | .978 |
| .72 | 4.808 | 2.546 | 2.262 | .756 | 272.1 | 4.750 | .244 | 87.9 | 1.533 | 1.749 | .965 |
| .73 | 4.856 | 2.562 | 2.294 | .760 | 273.7 | 4.775 | .240 | 86.3 | 1.508 | 1.752 | .952 |
| .74 | 4.903 | 2.578 | 2.325 | .765 | 275.4 | 4.807 | .235 | 84.6 | 1.477 | 1.756 | .939 |
| .75 | 4.951 | 2.595 | 2.356 | .770 | 277.2 | 4.838 | .230 | 82.8 | 1.445 | 1.759 | .924 |
| .76 | 5.000 | 2.612 | 2.388 | .775 | 279. | 4.869 | .225 | 81. | 1.414 | 1.763 | .909 |
| .77 | 5.049 | 2.630 | 2.419 | .780 | 280.8 | 4.901 | .220 | 79.3 | 1.382 | 1.766 | .895 |
| .78 | 5.100 | 2.649 | 2.451 | .785 | 282.6 | 4.932 | .215 | 77.4 | 1.351 | 1.770 | .879 |
| .79 | 5.148 | 2.666 | 2.482 | .790 | 284.4 | 4.964 | .210 | 75.6 | 1.319 | 1.773 | .863 |
| .80 | 5.198 | 2.684 | 2.514 | .795 | 286.2 | 4.995 | .205 | 73.8 | 1.288 | 1.776 | .848 |
| .81 | 5.247 | 2.702 | 2.545 | .800 | 288.1 | 5.027 | .200 | 71.9 | 1.257 | 1.779 | .832 |
| .82 | 5.298 | 2.722 | 2.576 | .806 | 290.1 | 5.064 | .194 | 69.9 | 1.219 | 1.782 | .814 |
| .83 | 5.349 | 2.741 | 2.608 | .811 | 292.1 | 5.096 | .189 | 67.9 | 1.188 | 1.786 | .796 |
| .84 | 5.400 | 2.761 | 2.639 | .817 | 294.2 | 5.133 | .183 | 65.8 | 1.150 | 1.790 | .777 |
| .85 | 5.452 | 2.781 | 2.671 | .823 | 296.4 | 5.171 | .177 | 63.6 | 1.112 | 1.794 | .757 |
| .86 | 5.504 | 2.802 | 2.702 | .829 | 298.6 | 5.209 | .171 | 61.4 | 1.074 | 1.797 | .736 |
| .87 | 5.556 | 2.822 | 2.734 | .836 | 300.9 | 5.253 | .164 | 59.1 | 1.030 | 1.801 | .714 |
| .88 | 5.609 | 2.844 | 2.765 | .842 | 303.2 | 5.290 | .158 | 56.8 | .993 | 1.805 | .692 |
| .89 | 5.662 | 2.866 | 2.796 | .849 | 305.6 | 5.334 | .151 | 54.4 | .949 | 1.809 | .668 |
| .90 | 5.716 | 2.888 | 2.828 | .856 | 308.2 | 5.378 | .144 | 51.8 | .905 | 1.812 | .642 |
| .91 | 5.769 | 2.910 | 2.859 | .864 | 311. | 5.429 | .136 | 49. | .855 | 1.816 | .613 |
| .92 | 5.824 | 2.933 | 2.891 | .872 | 313.9 | 5.479 | .128 | 46.1 | .804 | 1.821 | .582 |
| .93 | 5.879 | 2.957 | 2.922 | .880 | 316.9 | 5.529 | .120 | 43.1 | .754 | 1.826 | .550 |
| .94 | 5.935 | 2.981 | 2.954 | .889 | 320. | 5.586 | .111 | 40. | .697 | 1.830 | .516 |
| .95 | 5.992 | 3.007 | 2.985 | .899 | 323.6 | 5.649 | .101 | 36.4 | .635 | 1.835 | .475 |
| .96 | 6.047 | 3.031 | 3.016 | .910 | 327.6 | 5.718 | .090 | 32.4 | .565 | 1.840 | .429 |
| .97 | 6.105 | 3.057 | 3.048 | .922 | 331.9 | 5.793 | .078 | 28.1 | .490 | 1.846 | .374 |
| .98 | 6.165 | 3.086 | 8.079 | .937 | 337.2 | 5.887 | .063 | 22.8 | .396 | 1.853 | .312 |
| .99 | 6.223 | 3.112 | 3.111 | .955 | 343.8 | 6.000 | .045 | 16.2 | .283 | 1.861 | .228 |
| 1. | 6.284 | 3.142 | 3.142 | 1. | 360. | 6.283 | 0. | 0. | 0. | 1.879 | 0. |

Illustration of the Use of the Tables.—I. *To find the length of a crossed belt passing over two pulleys, knowing the radii and the distance between the centres.* Divide the sum of the radii by the distance between the centres, and, with the quotient as argument, seek the corresponding number in column 2 of the table, and multiply it by the distance between centres.

*Example:* What is the length of a crossed belt passing over two pulleys whose diameters are 5 and 3 feet respectively, the distance between centres being 10 feet, and thickness of belt one-quarter of an inch?

| | |
|---|---|
| Effective radii .................................................... | 30.125 |
| | 18.125 |
| Divide by distance between centres.............................. | 120)48.250 |
| | .40 |

Corresponding number in column 2, 3.419. $3.419 \times 10 = 34.2$ feet length of belt.

Note.—The effective radius (radius + $\frac{1}{2}$ thickness of belt) or effective diameter (diameter + thickness of belt) of pulley should generally be used in calculations involving these elements. In dividing sum or difference of radii by distance between centres, both terms must be expressed in the same unit (feet, inches, or the like), such unit being taken as is most convenient. In multiplying the resulting constant by the distance between centres, this latter term may be expressed in any denomination, and the answer will be in the same denomination. Thus, in the above example, the sum of the radii was taken in inches, and hence the sum was divided by the distance between centres expressed in inches, but the resulting constant was multiplied by the distance between centres in feet, giving the length of the belt in feet.

II. *To find the length of an open belt passing over two pulleys.* 1. Divide the difference of the radii by the distance between centres, and, using the quotient as argument, find the corresponding constant in column 3. 2. Divide the sum of the radii by the distance between centres, and find the corresponding constant in column 4. 3. Multiply the sum of these constants by the distance between centres.

*Example:* Find the length of an open belt passing over two pulleys whose effective radii are 20 and 10 inches respectively, the distance between centres being 12 feet.

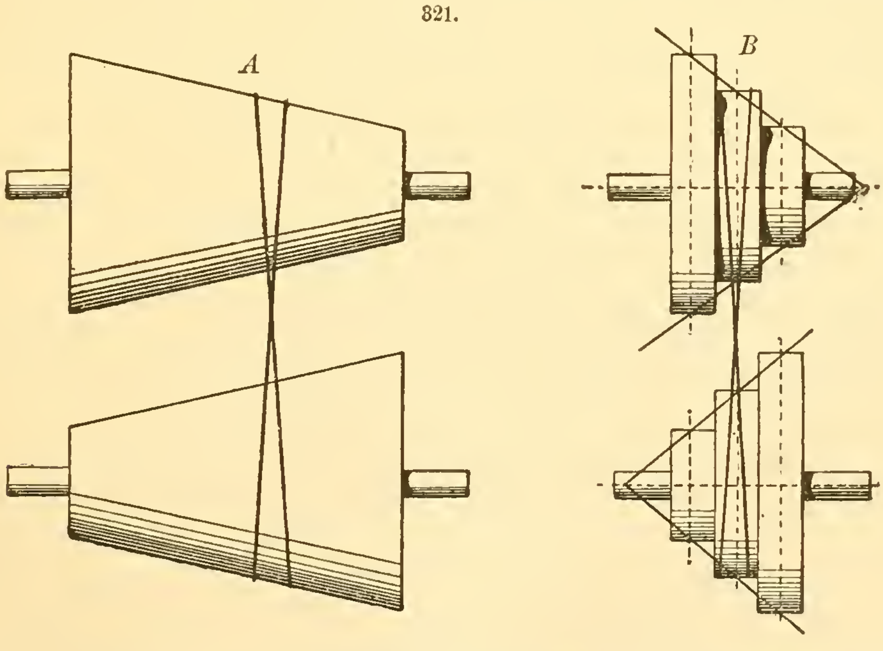
$$\frac{\text{Difference of radii}}{\text{Distance between centres}} = .07 \ldots\ldots\ldots\ldots \text{Corresponding constant} = 2.005$$

$$\frac{\text{Sum of radii}}{\text{Distance between centres}} = .21 \ldots\ldots\ldots\ldots \quad \text{“} \qquad \text{“} \quad = \ \underline{.660}$$

$$\text{Length of belt} = 32 \text{ feet} = 12 \times 2.665$$

III. *To design a pair of cone pulleys for a crossed belt.—a. Continuous cones* (Fig. 321, *A*). In this case it is only necessary to use two similar conical drums, with their large and small ends turned

321.



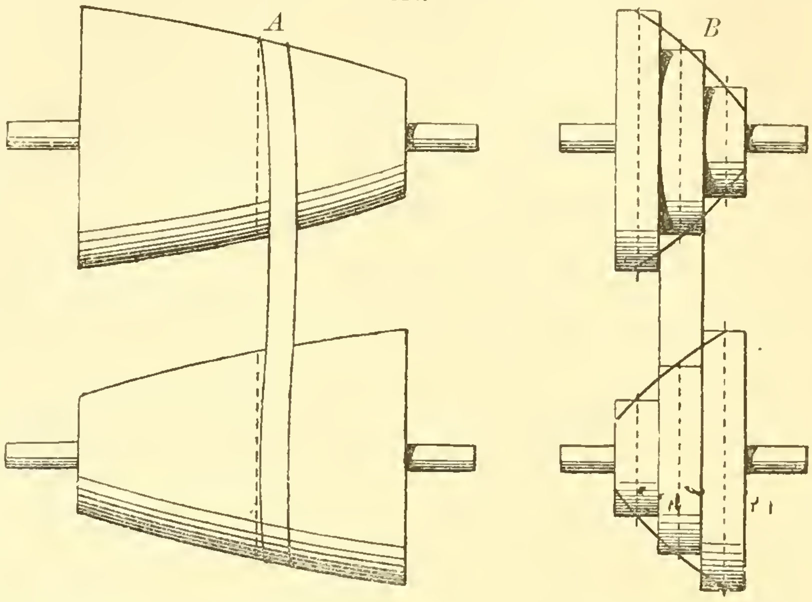

opposite ways. *b. Stepped cones, equal and opposite* (Fig. 321, *B*). Divide a pair of equal and opposite conoids into any number of equal parts by lines at right angles to the axes. The points in which these lines cut the faces of the conoids determine the several steps. *c. Any two stepped cones.* Assume values for the several radii of one of the cones, and give such values to the corresponding radii of the second cone that the sum of each pair shall be the same.

*Example:* Suppose the several radii of one cone pulley are 12, 10, 8, 6, and 4 inches, and that the smallest radius of the other stepped cone is 3 inches. This fixes the sum of each pair of radii at 15 inches, so that the remaining radii will be 5, 7, 9, and 11 inches.

IV. *To design a pair of cone pulleys for an open belt.—a. Continuous cones* (Fig. 322, *A*). Equal and similar conoids must be used. Assume extreme radii, and, knowing distance between centres,

calculate the length of belt required. To find the middle radius, subtract twice the distance between centres from the length of the belt, and divide the difference by 6.2832. Draw arcs of circles through extreme and middle points, thus determining the sections of the conoids.

322.




*Example:* Given largest radius of conoid 24 inches, smallest radius 6 inches, distance between centres 3 feet. What should be the middle radius? By means of the table and preceding rule, the length of belt is found to be 14.6 feet.

$\frac{14.6 - 6}{6.2832} = 1.37$ feet, about $16\frac{1}{2}$ inches, middle radius.

*b. Stepped cones, equal and opposite* (Fig. 322, *B*). Form two continuous conoids in the manner explained above, and divide them into the required number of steps. *c. Any two stepped cones.* Assume one pair of radii, and calculate the length of the belt for the given distance between centres. Assume at pleasure the difference between a second pair of radii, divide this assumed value by the distance between centres, find the number corresponding to this quotient in column 3 of the table, multiply it by the distance between centres, and subtract the product from the length of the belt. Divide the remainder by the distance between centres, and find the argument corresponding to this quotient in column 4. Multiplying this argument by the distance between centres gives the sum of the second pair of radii. The larger radius can be found by adding the half difference to the half sum, and the smaller radius by subtracting the half difference from the half sum. The application of this rule is very simple, as the following example will show:

First pair of radii, 12 and 4 inches; distance between centres, 3 feet. Find another pair of radii that will give the same length of belt, their difference being $1\frac{1}{2}$ inch. Calculating the length of belt, it is found to be 10.3 feet. $1.5 \div 36 = .04$. Corresponding number in column 3, 2.001. $10.3 - 2.001 \times 3 = 4.3$; $4.3 \div 3 = 1.433$. Corresponding argument $= .46$; $.46 \times 36 = 16.56 =$ sum of required radii.

$$\text{Larger radius} = \frac{16.56 + 1.5}{2} = 9. + \text{inches.}$$

$$\text{Smaller radius} = \frac{16.56 - 1.5}{2} = 7.5 + \text{inches.}$$

Another rule, requiring only one radius and the distance between centres to be given, in order to determine the other radius, will be found among the formulas that follow these illustrations.

V. *To find the arc of contact between a belt and a pulley.*

First Method.—Measure the length of the portion of the circumference of the pulley that is in contact with the belt, and the diameter of the pulley. Divide the first measurement by the radius of the pulley, and in the same horizontal line with the quotient in column 7 or 10 will be found in columns 5, 6, or 8, 9, the fraction of circumference in contact with the belt, and the angle of contact.

*Example:* The length of the arc of contact of a belt with a pulley is 15.3 feet, and the diameter of the pulley is 10 feet. $15.3 \div 5 = 3.06$, and by reference to column 10 it will be seen that the arc of contact is .487 of the circumference, corresponding to an angle of 175·4°.

Second Method.—*a. Crossed belt.* Divide the sum of the radii by the distance between the centres of the pulleys, and with the quotient as argument in column 1 find the required data in columns 5, 6, and 7.

*Example:* A crossed belt passes over two pulleys whose radii are 4 and 3 feet respectively, and the distance between their centres is 12 feet. $(4 + 3) \div 12 = .58$; hence the arc of contact is .697 of the circumference, the angle of contact is 250.9°, the length of arc on larger pulley is $4.379 \times 4 = 17.516$ feet, and the length of arc on small pulley is $4.379 \times 3 = 13.137$ feet.

*b. Open belt.* Divide the difference of the radii of the two pulleys by the distance between their centres, and, with the quotient as argument in column 1, find the arc of contact for the large pulley, in columns 5, 6, and 7, and the arc of contact for the small pulley, in columns 8, 9, and 10.

*Example:* An open belt passes over two pulleys whose diameters are 6 and 4 feet, and the distance between whose centres is 9 feet. $(3 - 2) \div 9 = .11$; so that the arc of contact for the large pulley is .535 of the circumference, the angle is 192.6°, and the length $3.362 \times 3 = 10.086$ feet; and for the small pulley, .465 of the circumference, the angle is 167.4°, and the length $2.922 \times 2 = 5.844$ feet.

Note.—In the rules given in the second method, it is assumed that the belt is drawn perfectly tight between the pulleys. Where there is much deviation from this in practice, it is better to

employ the first method. It frequently happens that the arc of contact, when the belt is at rest, is materially changed when motion ensues. At very fast speeds, the centrifugal force often reduces the arc of contact considerably; and as the power that a belt can transmit varies with this arc, its value should be estimated under the conditions that occur when the belt is running.

VI. *To find the speed of a belt, in feet per minute.* Multiply the diameter of either pulley, in feet, by 3.1416 times the number of revolutions that it makes per minute.

*Example:* A belt passes over a pulley that is 16 feet in diameter, and makes 60 revolutions per minute. Speed of belt $= 16 \times 3.1416 \times 60 = 3{,}016$ feet per minute.

VII. *To find the power that can be transmitted by a single leather belt of given width passing over smooth iron pulleys.* Find, in column 11 or 12, the power corresponding to arc of contact of the belt with the small pulley; multiply this by the speed of belt in feet per minute, and the width of belt in inches, and point off three figures of the product to the right. The result will be the horse-power transmitted.

*Example:* A 10-inch belt, moving at the rate of 4,000 feet a minute, makes an angle of contact with the small pulley of 120°. $1.187 \times 4.000 \times 10 = 47.48$ horse-power.

VIII. *To find the width of belt required to transmit a given amount of power.* Find the power transmitted by a belt 1 inch wide, under the given conditions, and divide the amount of power that is to be transmitted, by the quantity so found.

*Example:* A belt is to have a speed of 1,500 feet a minute, and to make an arc of contact of 210° with the small pulley. How wide will it require to be to transmit 15 horse-power?

Power transmitted by a belt 1 inch wide $= 1.592 \times 1.500 = 2.388$ horse-power. Width of belt required $= 15 \div 2.388 = 6.3$ inches.

NOTE.—In these rules the coefficient of friction between the belt and the pulley is taken at .423, and it is assumed that a safe working strain for a single leather belt, with the ends secured by lace-leather, is $66\frac{2}{3}$ lbs. per inch of width. In speaking of the width of a belt, the effective width is meant, or that portion of the width in contact with the pulley; so that, for example, if the belt only bears for two-thirds of its width, and is 9 inches wide, the width to be used in the calculations will be 6 inches. If, instead of leather, rubber belts are used, the above rules may be employed, observing that, under the same circumstances, a rubber belt will transmit one-fourth more power than a leather one. Pulleys are sometimes covered with leather or rubber, in order to increase the friction. Mr. J. W. Sutton has made numerous experiments in order to determine the best form of covering, and has patented a composition which is secured to the face of the pulley, and which he claims will increase the transmitting power of a belt fully 100 per cent.

The analytical expressions on which the table and rules depend are appended, together with formulas for finding the radius of a pulley when the other radius and the distance between centres are given. It may be well to illustrate the use of the latter.

Suppose a pulley has a radius of 4 feet, and the distance between its centre and the other pulley is 12 feet. What should be the radius of the other pulley, if the length of an open belt passing over the two pulleys is 56 feet?

First find whether the given radius is the large or small one. $4 \times 3.1416 + 12 = 24.6$; and as this is less than $56 \div 2 = 28$, the given radius is the smaller of the two. Then, according to the formula, the other radius =

$$4 + 12 \times \left(\sqrt{0.4674 + \frac{56 - 6.2832 \times 4}{12}} - 1.5708\right) = 6.07 \text{ feet.}$$

*Notation.*

$R =$ radius of larger pulley. $r =$ radius of smaller pulley. $S =$ distance between centres of pulleys. $L =$ length of belt. $F =$ force in lbs. transmitted by a single leather belt, 1 inch wide. $W =$ width of belt, in inches. $P =$ horse-power transmitted by belt. $V =$ velocity of belt, in feet per minute. $N =$ revolutions of pulley per minute. $a =$ arc of contact of belt with pulley, in degrees. $a =$ fraction of circumference of pulley in contact with belt. $A =$ length of arc of contact, for a radius of 1.

*Crossed Belt.*

$$L = 2\sqrt{S^2 - (R + r)^2} + (R + r) \times \left(3.1416 + 2 \text{ arc. sine} \frac{R + r}{S}\right).$$

For stepped cones, the only condition is $R + r =$ a constant.

$$a = 180° + 2 \text{ angle. sine} \frac{R + r}{S}.$$

*Open Belt.*

$$L = 2\sqrt{S^2 - (R - r)^2} + 3.1416 \times (R + r) + (R - r) \times 2 \text{ arc. sine} \frac{R - r}{S}.$$

For continuous cone of pulleys, middle radius of conoid $= \dfrac{L - 2S}{6.2832}$.

If (assumed radius $\times\ 3.1416 + S) > \dfrac{L}{2}$, the assumed radius is $R$.

If (assumed radius $\times\ 3.1416 + S) < \dfrac{L}{2}$, the assumed radius is $r$.

If $R$ is assumed, $r = R - S \times \left(1.5708 - \sqrt{0.4674 + \frac{L - 6.2832 \times R}{S}}\right)$.

If $r$ is assumed, $R = r + S \times \left(\sqrt{0.4674 + \frac{L - 6.2832 \times r}{S}} - 1.5708\right)$. $a = 180° - 2 \text{ angle. sine} \frac{R-r}{S}$.

*General Formulas, Crossed or Open Belt.*

$$V = 6.2832 \times R \times N = 6.2832 \times r \times N, \quad a = \frac{a}{360°}, \quad A = a \times 6.2832,$$

$$F = 66\tfrac{2}{3} \times \left(1 - 0.1^{0.003206 \times a}\right), \quad P = \frac{F \times W \times V}{33{,}000}, \quad W = \frac{33{,}000\,P}{F \times V}.$$

In the United States, transmission of power by large belts is more common than in Europe, and probably the largest belts in the world are to be found in this country. Mr. J. H. Cooper, in a letter published in "Engineering," * gives several instances of large belts, from which the following are selected:

The driving-belt of the New Jersey Zinc Works is of leather, 4 thicknesses, 48 inches wide and 102 feet long.

An elevator in Chicago has a rubber belt, 6 ply, 48 inches wide and 320 feet long.

These belts have been in use for a number of years, with very satisfactory results.

Messrs. J. B. Hoyt & Co. exhibited at the Centennial Exposition a leather belt 5 feet wide and 186½ feet in length, made for a paper-mill in Wilmington, Delaware.

Hemp ropes, running in grooved pulleys, have been used instead of flat belts for transmitting power. The grooves in the pulleys are V-shaped, the sides of the V making an angle of 40° with each other. A pulley usually has several grooves, so that the strain is distributed between two or more ropes. Mr. James Durie, in a paper read before the Institution of Mechanical Engineers at Manchester,† gives some examples of the use of rope-belting, and thinks its general adoption is very desirable, because it is much cheaper than leather or rubber, and transmits power in a very satisfactory manner. The ropes used are from 5¼ to 6½ inches in circumference, and are connected at the ends by long splices of 9 or 10 feet. They can be run at a speed of 6,000 feet a minute, if used over pulleys having a diameter not less than thirty times that of the ropes. Mr. Durie gives examples of the application of rope-belting, working with tension varying from 256 to 349 lbs. for each rope. In one case 18 driving ropes were used, each transmitting about 23 horse-power at a speed of 2,967 feet per minute. In another example, about 1,000 horse-power was transmitted by 25 ropes, at a speed of 3,784 feet a minute, or at the rate of 40 horse-power for each rope. The ropes, in both cases, were 6½ inches in circumference. Taking the average value of the working tension for such ropes at 300 lbs., the horse-power transmitted would be (300 × speed in feet per minute) ÷ 33,000 for each rope, and the number of ropes required for any case would be the quotient of the whole power divided by the power of a single rope.

Suppose, for instance, it is required to transmit 350 horse-power by ropes 6½ inches in circumference, at a speed of 4,000 feet a minute. Each rope would transmit 300 × 4,000 ÷ 33,000 = 36.45 horse-power, and the number of ropes required would be 350 ÷ 36.45 = 10.

For the transmission of power over great distances, wire cables running in V-shaped pulleys, or *telodynamic cables*, are frequently employed. This mode of transmission is very much cheaper than either belts or shafting, where the distance is considerable. The plan is the invention of the Brothers Hirn, of Switzerland. It is found that the cables can be safely run at a speed of about a mile a minute, and that the average life of an uncovered cable is about three years. For distances exceeding 300 or 400 feet, intermediate carrying sheaves are used to support the cable, or intermediate stations may be employed at these intervals apart. The best filling for the pulleys, in the case of an uncovered cable, seems to be leather, forced in radially in wedge-shaped pieces. Cables, with a covering of cotton yarn, are also made, which, although quite expensive, are said to be very durable, and can be run on pulleys that have no filling. Cables are made both with hemp and wire centres, but the former are preferable, on account of their greater flexibility. The lightness of the mechanism and the high velocity employed render telodynamic transmission very efficient. Mr. Albert W. Stahl, who has written a very useful treatise on wire-rope transmission,‡ estimates the power transmitted to be 97.5 per cent. of the power applied, if there are no carrying sheaves, with a deduction of $\frac{13}{100}$ per cent. of the applied power for each carrying sheave that is added. He also states that the average cost of telodynamic cables, with the necessary gearing, is about one-fifth that of belts, and one-twenty-fifth that of shafting. R. H. B.

BESSEMER PROCESS. See Steel.

BETON. See Concretes and Cements.

BICK IRON, or BEAK IRON. A small anvil having a tang, which is inserted in a hole in the work-bench.

BINARY ENGINE. See Engines, Aëro-Steam and Binary Vapor.

BINDER, GRAIN. See Agricultural Machinery.

BINK. In cotton manufacture, a stack of cotton laid in successive layers from different bales; the object being to mix the cotton.

BINOT. A species of double mould-board plough.

BITS AND AUGERS. The term *bit* is applied to all exchangeable boring-tools. Most of these

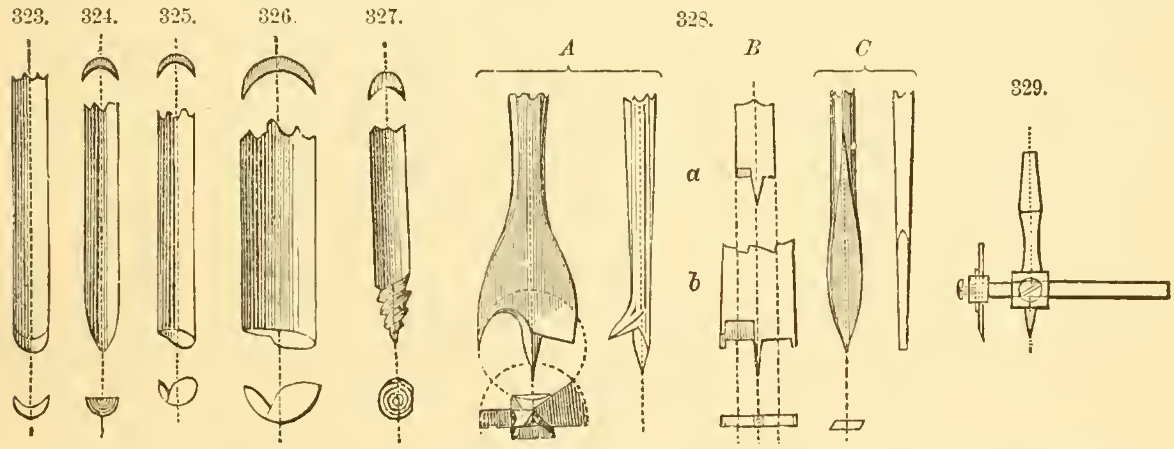
* Vol. xvii. p. 408. † *Engineering*, xxii., 394.
‡ "Transmission of Power by Wire Ropes." By Albert W. Stahl, M. E. New York, 1877.

implements in carpentry are fluted like reeds split in two parts, to give room for the shavings; and they are sharpened in various ways, as shown in Figs. 323 to 327.* Fig. 323 is known as the *shell-bit*, and also as the *gouge-bit*, or *quill-bit;* it is sharpened at the end like a gouge, and when revolved it shears the fibres around the margin of the hole, and removes the wood almost as a solid core. The shell-bits are in very general use; and when made very small, they are used for boring the holes in some brushes.

Fig. 324, the *spoon-bit*, is generally bent up at the end to make a taper point, terminating on the diametrical line; it acts something after the manner of a common pointed drill, except that it possesses the keen edge suitable for wood. The spoon-bit is in very common use; the *coopers' dowel-bit*, and the *table-bit*, for making the holes for the wooden joints of tables, are of this kind. Occasionally, the end is bent in a semicircular form; such are called *duck-nose-bits*, from their resemblance, and also *brush-bits*, from their use. The diameter of the hole continues undiminished for a greater depth than with the pointed spoon-bit.

The *nose-bit*, Fig. 325, called also the *slit-nose-bit* and *auger-bit*, is slit up a small distance near the centre, and the larger piece of the end is then bent up nearly at right angles to the shaft, so as to act like a paring-chisel; and the corner of the reed, near the nose, also cuts slightly. The form of the nose-bit, which is very nearly a diminutive of the *shell-auger*, Fig. 326, is better seen in the latter instrument, in which the transverse cutter lies still more nearly at right angles, and is distinctly curved on the edge instead of radial. The augers are sometimes made 3 inches diameter and upward, and with long removable shanks, for the purpose of boring wooden pump-barrels; they are then called *pump-bits*.

There is some little uncertainty of the nose-bit entering exactly at any required spot, unless a small commencement is previously made with another instrument, as a spoon-bit, a gouge, a brad-awl, a centre-punch, or some other tool; with augers a preparatory hole is frequently made, either with a gouge, or with a centre-bit exactly of the size of the auger. When the nose-bits are used for making the holes in sash bars, for the wooden pins or dowels, the bit is made exactly parallel, and it has a square brass socket which fits the bit; so that, the work and socket being fixed in their respective




situations, the *guide-principle* is perfectly applied. A "*guide-tube*" built up as a tripod, which the workman steadies with his foot, has been applied for boring the auger-holes in railway sleepers exactly perpendicular.

The gimlet, Fig. 327, is also a fluted tool, but it terminates in a sharp worm or screw, beginning as a point and extending to the full diameter of the tool, which is drawn by the screw into the wood. The principal part of the cutting is done by the angular corner intermediate between the worm and shell, which acts much like the auger. The gimlet is worked until the shell is full of wood, when it is unwound and withdrawn to empty it.

The centre-bit, *A*, Fig. 328, shown in three views, is a very beautiful instrument. It consists of three parts: a centre-point or *pin*, filed triangularly, which serves as a guide for position; a thin shearing-point or *nicker*, that cuts through the fibres like the point of a knife; and a broad chisel-edge or *cutter*, placed obliquely to pare up the wood within the circle marked out by the point. The cutter should have both a little less radius and less length than the nicker, upon the keen edge of which last the correct action of the tool principally depends.

Many variations are made from the ordinary centre-bit, *A*, Fig. 328. Sometimes the centre-point is enlarged into a stout cylindrical plug, so that it may exactly fill a hole previously made, and cut out a cylindrical countersink around the same, as for the head of a screw-bolt. This tool, known as the *plug centre-bit*, is much used in making frames and furniture, held together by screw-bolts. Similar tools, but with loose cutters inserted in a diametrical mortise, in a stout shaft, are also used in ship-building for inlaying the heads of bolts and washers in the timbers and planking.

The *wine-cooper's centre-bit* is very short, and is enlarged behind into a cone, so that immediately a full cask has been bored, the cone plugs up the hole until the tap is inserted. The centre-bit deprived of its chisel-edge, or possessing only the pin and nicker, is called a *button-tool;* it is used for boring and cutting out, at one process, the little leather disks or *buttons* which serve as nuts for the screwed wires in the mechanism connected with the keys of the organ and pianoforte.

The *expanding centre-bit*, shown on a much smaller scale in Fig. 329, is a very useful instrument; it has a central stem with a conical point, and across the end of the stem is fitted a transverse bar

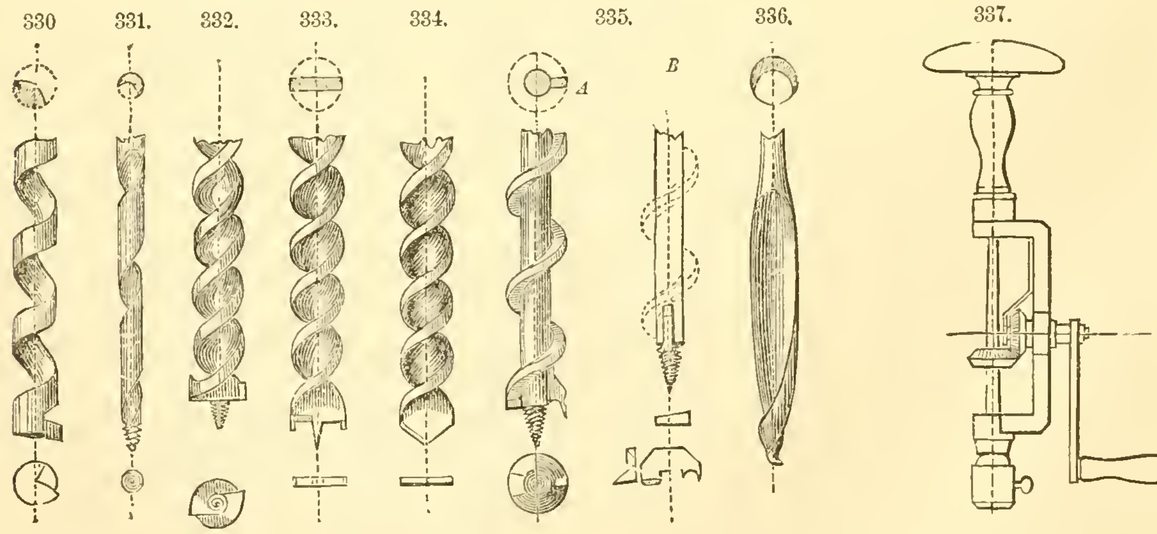
* Holtzapffel's "Turning and Mechanical Manipulation."

adjustable for radius. When the latter carries only a lancet-shaped cutter, it is used for making the margins of circular recesses, and also for cutting out disks of wood and thin materials generally. A modification of this device serves for making grooves for inlaying rings of metal or wood in cabinet-work, and other purposes. Another form of expanding bit has a cutting-blade which passes through a mortise in the head of the tool and is secured by a key. This may be adjusted radially to bore holes of different sizes.

The above tools being generally used for woods of the softer kinds, and the plankway of the grain, the shearing-point and oblique chisel of the centre-bit are constantly retained; but the corresponding tools used for the hard woods assume the characters of the hard-wood tools generally. For instance, *a*, Fig. 328 (*B*), has a square point, also two cutting edges, which are nearly diametrical, and sharpened with a single chamfer at about 60°; this is the ordinary *drill* used for boring the finger-holes in flutes and clarionets, which are afterward chamfered on the inner side with a stout knife, the angle of the edge of which measures about 50°. The key-holes are first scored with the *cup-key tool*, *b*, and then drilled, the tools *a* and *b* being represented of corresponding sizes, and forming between them the annular ridge which indents the leather of the valve or key. When *a* is made exactly parallel and sharpened up the sides, it cuts hard mahogany very cleanly in all directions of the grain, and is used for drilling the various holes in the small machinery of pianofortes; this drill (and also the last two) is put in motion in the lathe; and in the lathe-drill for hard woods, *C*, Fig. 328, called by the French *langue de carpe*, the centre-point and the two sides melt into an easy curve, which is sharpened all the way round and a little beyond its largest part. Various tools for boring wood are made with spiral stems, in order that the shavings may be enabled to ascend the hollow worm, and thereby save the trouble of so frequently withdrawing the bit. For example, the shaft of Fig. 330, the *single-lip auger*, is forged as a half-round bar, nearly as in the section shown; it is then coiled into an open spiral, with the flat side outward, to constitute the cylindrical surface, and the end is formed almost the same as that of the shell-auger, Fig. 326. The *twisted gimlet*, Fig. 331, is made with a conical shaft, around which is filed a half-round groove, the one edge of which becomes thereby sharpened, so as gradually to enlarge the hole after the first penetration of the worm, which, from being smaller than in the common gimlet, acts with less risk of splitting. The ordinary screw-auger, Fig. 332, is forged as a parallel blade of steel (seen in Fig. 333, which also refers to 332 and 334); it is twisted red-hot. The end terminates in a worm by which the auger is gradually drawn into the work, as in the gimlet, and the two angles or lips are sharpened to cut at the extreme ends, and a little up the sides also. Augers are also cast in two-part flasks, swaged between dies, or twisted by successive motions of the parts of sectional dies. The same kind of shaft is sometimes made as in Fig. 333, with a plain conical point, with two scoring-cutters and two chisel-edges, which receive their obliquity from the slope of the worm; it is as it were a double centre-bit, or one with two lips grafted on a spiral shaft. The same shaft has been also made, as in Fig. 334, with a common drill-point, for metal.

Another screw-auger, which is sometimes used instead of the double-lipped screw-auger, Fig. 332, is known as the *American screw-auger*, and is shown in Fig. 335, *A* and *B*. This has a cylindrical shaft, around which is brazed a single fin or rib; the end is filed into a worm as usual, and immediately behind the worm a small diametrical mortise is formed for the reception of a detached cutter, which exactly resembles the nicking-point and chisel-edge of the centre-bit; it may be called a centre-bit for deep holes. The parts are shown detached at *B*. The loose cutter is kept central

330 331. 332. 333. 334. 335. 336. 337.




by its square notch, embracing the central shaft of the auger; it is fixed by a wedge driven in behind, and the chisel-edge rests against the spiral worm.

*Taper augers* are used for reaming out bung-holes, making butter-prints, etc. The centre-bit bores a hole, and is succeeded by the taper reamer, which has a throat for the chips cut through from the edge of the bit on one side to the opposite side of the stock.

An auger applicable to producing square holes, and those of other forms, is also an American invention. The tool consists of a steel tube, of the width of the hole; the end of the tube is sharpened from within, with the corners in advance, or with four hollowed edges. In the centre of the square tube works a screw-auger, the thread of which projects a little beyond the end of the tube,

so as first to penetrate the wood, and then to drag after it the sheath, and thus complete the hole at one process; the removed shavings making their escape up the worm and through the tube.

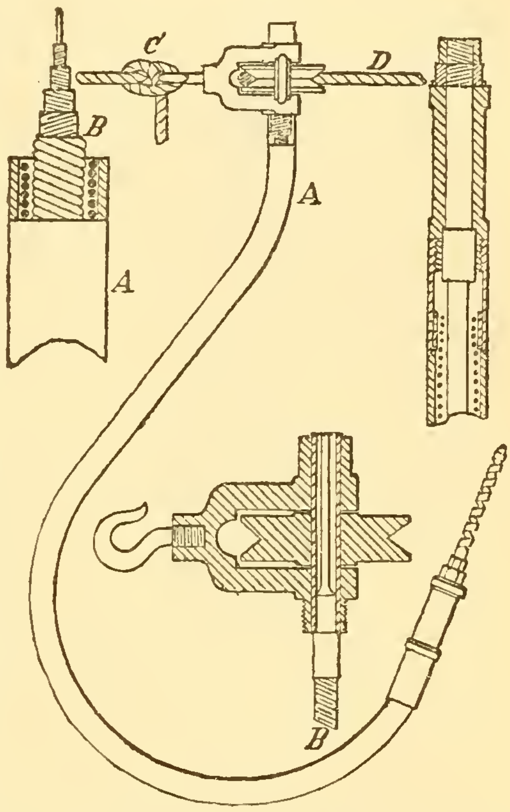
*Hollow augers* are used for forming tenons on spokes, chair-legs, etc. In one form the cutting tool is so attached as to project within the opening, and the size of the tenon is regulated by the adjustment of the angular rest.

*Annular augers* cut an annular groove, leaving wood on the inside and outside of its channel.

*The slotting auger* cuts laterally, the work being fed against its sides. A number of chisel-shaped lips are formed on the edges of the twist.

The most usual of the modes of giving motion to the various kinds of boring bits is by the ordinary carpenter's brace with a crank-formed shaft. The instrument is made in wood or metal, and at the one extremity has a metal socket called the *pad*, with a taper square hole, and a spring catch used for retaining the drills in the brace when they are withdrawn from the work; and at the other it has a swiveled head or shield, which is pressed forward horizontally by the chest of the workman, or, when used vertically, by the left hand, which is then commonly placed against the forehead.

338.




The ordinary carpenter's brace is too familiarly known to require further description, but it sometimes happens that in corners and other places there is not room to swing round the handle. The *angle-brace*, Fig. 337, is then convenient. It is made entirely of metal, with a pair of bevel-pinions, and a winch-handle that is placed on the axis of one of these, at various distances from the centre, according to the power or velocity required. Sometimes the bevel-wheel attached to the winch-handle is three or four times the diameter of the pinion on the drill; this gives greater speed, but less power.

The augers, which from their increased size require more power, are moved by transverse handles; some augers are made with *shanks*, and are riveted into the handles just like the gimlet; occasionally the handle has a socket or pad, for receiving several augers, but the most common mode is to form the end of the shaft into a ring or eye, through which the transverse handle is tightly driven. The brad-awls, and occasionally the other tools requiring but slight force, are fitted in straight handles; many of the smaller tools are attached to the lathe-mandrel by means of chucks, and the work is pressed against them, either by the hand, or by a screw, a slide, or other contrivance.

Among the recent improvements in hand-boring appliances is the flexible auger illustrated in Fig. 338, which is manufactured by Messrs. Stow and Burnham, of Philadelphia. It consists simply of a flexible tube lined with a spiral wire, and through which is passed a closely-coiled spiral, having at each end suitable connections for a small sheave and for the auger respectively. These details are clearly shown in the drawing. A link passes around the sheave and has a hook attached to it, for the purpose of holding a tension-rope when the auger is in use. The sheave is driven by a cord from a countershaft direct, or through a system of pulleys when the work to be done is removed to any distance. The largest-sized auger yet made is one inch, which is worked by a one-inch cable; and the smaller sizes range from three-eighths of an inch upward, increasing by eighths of an inch; the longest cable hitherto employed is 15 feet. This device may also be adapted for metal-drilling.

For metal-boring implements, see Drills, and Drilling and Boring-Machines. See also Well-Boring.

BLAST FURNACE. See Furnaces, Blast.

BLASTING. The process of breaking rocks with explosive compounds. In ordinary blasting operations, simple drill-holes are usually fired, and may be so placed and combined in groups as to effect the displacement of great masses of rock; but in large operations mines are excavated for the introduction of the explosive.

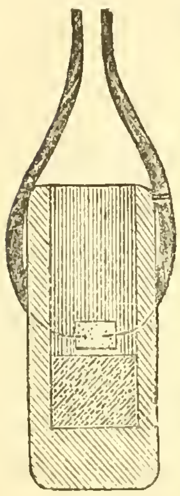
The blowing up of rock by gunpowder is a simple process. The hole is bored in the rock, and in such direction as to expose the weakest part to the action of the powder; this hole is charged with a certain portion of gunpowder, and is then filled with clay, or, more usually, with a soft kind of rock, which is rammed into it, leaving a small orifice, through which the fuse is afterward introduced for setting fire to it. At the present day, a variety of tubular fuse is used in the coal-regions of Pennsylvania, where a long iron tube is used, and the firing done with a straw or a Daddow squib. A narrow ribbon of copper is used as covering material for the squib, and is folded spirally around the core, through which passes a string coated with mealed powder or any other combustible material, and intended to insure quick and certain ignition. These squibs are found cheap and reliable. Bickford's fuse is used in cases where it is not desired to fire several charges at once. When used with gun-cotton and nitro-glycerine or any compounds of the latter, all of which have to be detonated by a cap of fulminating powder, the fuse is slightly rasped at the end and inserted into the cap.

Electrical firing is generally used for simultaneous blasting; by it, ignition of the charge is effected

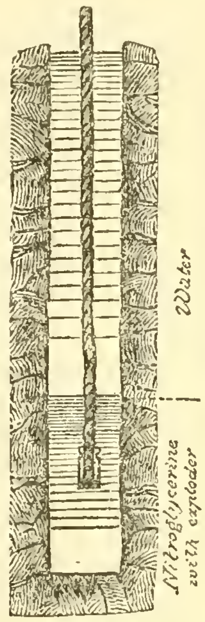
in two ways. One is by interposing an exceedingly fine platinum wire (iron or alloyed metal will also answer) in the path of a current of electricity from a powerful voltaic battery, the resistance offered by the diminished conducting power of the fine wire to the passage of the electric current heating the wire to redness, and thereby exploding the charge. Another system of electrical blasting depends upon a sudden discharge of static electricity between the terminals of two wires imbedded in a suitable priming composition, which is thereby fired. For this, various appliances have been used, viz: (*a.*) A frictional electric machine and Leyden jar; (*b.*) A voltaic battery induction coil; (*c.*) An electro-dynamic machine, such as Siemens's, Ladd's, Farmer's, Gramme's, etc.; (*d.*) An electro-dynamic machine, as Wheatstone's, Breguet's, Saxton's, Clarke's, etc.

Fig. 338 A shows the electrical fuse so called, made by the Laflin & Rand company, which belongs to the second system above noted, and which it is claimed will cause the detonation of common blasting powder. All of these caps or exploders are practically constructed on the same principle, and they are chiefly used in detonating charges of gun-cotton, nitro-glycerine, dynamite, and the other nitro-glycerine compounds.

338 A.



338 B.




Among the direct advantages of electric firing may be summarized: (*a.*) Simultaneous firing of different charges; (*b.*) Premature escape of any of the gas developed absolutely avoided by close tamping; (*c.*) No smoke or gas from fuses; (*d.*) Greatest safety; (*e.*) Rapidity of work.

*Tamping.*—With black powder, clay is perhaps best, but soft rock, sand, etc., are often substituted. With pure nitro-glycerine, no tamping is needed but water; therefore nitro-glycerine, having greater specific gravity than water and no affinity for it, is an especially suitable agent for subaqueous blasting, where it can simply be poured down into the holes through a tube and funnel. Fig. 338 B shows a charge of nitro-glycerine with water-tamping and tape-fuse and exploder. Where the rock is split or seamy, nitro-glycerine must be encased in some substance, say tin cases, and this, it is said, lessens its explosive force by preventing close contact. Where the rock is firm, it can be poured directly into the hole. In this respect, dynamite has a great advantage over nitro-glycerine, in that it can be charged in roof-holes and in seamy rock, there being no danger of running out, leakage, etc. In charging No. 1 dynamite, it was formerly thought that no tamping would be required, but the general experience of blasters has led to the practice of tamping the holes solidly to the lip with clay.

*The Principles of Blasting.*—The effect of a shot may be influenced, among other considerations, by: (*a.*) The shape in which the rock is presented, the size and number of the open faces, the shape of the piece it is desired to take out, if that be an object, and, of course, primarily, the size of the cross-section of the face, if it be heading work. (*b.*) The texture of the rock, whether it be hard or easy, firm or loose, whether it be brittle or tough; thus experience gained in blasting close-grained, hard granite, trap, gneiss, etc., would not apply to limestone, sandstone, slate, etc., etc. (*c.*) The structure of the rock, as to whether it be laminated, stratified, or fissured; upon its cleavage, etc., and upon whether it be massive or broken, etc. (*d.*) The elasticity of the rock. (*e.*) The explosive used. (*f.*) Whether the hole is to act alone or simultaneously with or following others; in the case of simultaneous firing, the question arises of how the waves of oscillation will best act in concert. (*g.*) The character of the fuse and tamping.

1. The hole should not be located in the line of least resistance, otherwise the tamping would simply be blown out. (Be it remembered this discussion is as to black powder, not nitro-glycerine.)

2. Experience has established the average ratio between the depth of hole and the length of the line of least resistance to be as 4 to 3, or the length of the line of least resistance will be three-quarters of the depth of the hole; and experience has further shown that the charge of black powder should be, on the average, about one-third of the depth of the hole, the varying limits being 0.29 to 0.45.

3. Holes ought in general to be bored at or under an angle of 45°; a larger angle, increasing to as much as 90°, is advisable when open faces occur, and a smaller angle is advisable when the texture and structure of the rock necessitate assuming the line of least resistance as less than three-quarters of the depth of the hole. Further, as the mass thrown breaks in the general direction of the line of least resistance, and as, in fact, this line lies in the mass ejected, or, in the extreme case of an angle of 90°, bounds the ejected mass, we must carefully observe,

4. The external shape of the rock, in order to reach a maximum effect,

5. Clefts and fissures and lines of stratification in the rock must be carefully used to advantage. In general, we may say, as to blasting in regularly stratified rock, that,

6. In regular seams, the shots should be set perpendicular to the face of the seam.

7. The portion of the hole holding the powder should be located within the whole rock. This rule, of course, only holds in rock where the strata are thicker than the depth of the powder-charge in the hole. If the charge intersect a stratification-bed, there will, in general, be a waste of force. Therefore, a short-fissured rock (i. e., one naturally broken by short clefts, etc.), or one much laminated, though it gives more faces for the powder to act on again, is ultimately less favorable material, in many cases, than more solid material; therefore,

8. Short-fissured, laminated, or slaty rock should not be drilled, if possible, in the direction of the laminæ, but, according to circumstances, in an oblique or normal direction to them. Not only should

9. Each shot be set so as to clear a bearing for following shots, but also

10. The proper volume should be blasted away.

11. Short-fissured or very tough rock requires shallow holes; coarse-fissured, moderately tough rock takes holes of average depth; and brittle and solid rock works well with deep holes. In tough rock wide holes, and in brittle rock narrow holes, are the more economical.

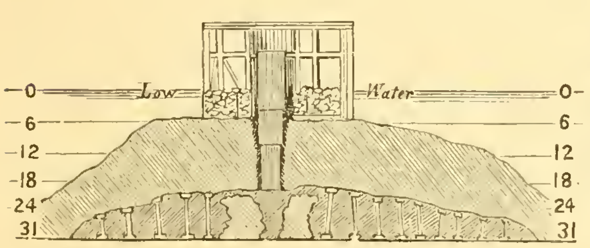
It should here be noted that *firm, brittle* rock may be distinguished by the rebound of the hammer; it drills hard, but breaks easily. Examples are: Trap, granite, gneiss, syenite, etc. *Firm, tough* rock does not cause the hammer to rebound so violently, leaves a white streak when scratched with steel, drills easy, but breaks hard. Examples are: Limestone, porphyry, quartzose lodes, etc.

12. In driving a heading, particular care should be taken that unnecessary cost in flushing the clear profile does not arise. Large protuberances and cavities must be avoided, and particular care in this respect should be paid in tunneling in taking out the bottom or bench, that there be not a large amount of trimming left to be subsequently done in clearing the normal profile, for such work is not only very tedious, delaying the work, but is costly. For this reason, holes located near the sides or roof should receive especial care.

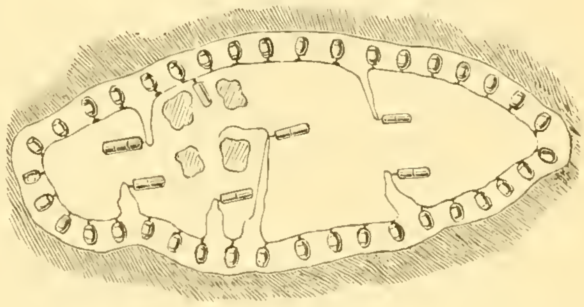
*Blossom Rock.*—The removal of Blossom Rock, in the harbor of San Francisco, is an example of the process of removing submarine rocks by conducting the excavation from within. Full particulars of this work are given in the official reports of Col. R. S. Williamson and Lieut. W. H. Heuer, U. S. A. The top of the rock was about 5 feet below the surface of the water at mean low tide. A horizontal section at the depth of 24 feet measured 195 by 105 feet. The quantity of rock contained within these boundaries was about 5,000 cubic yards, and consisted of a metamorphic sandstone of irregular stratification. The great mass of it was so soft as not to require blasting. The plan proposed by A. W. Von Schmidt involved the sinking of an iron cylinder 6 feet in diameter, carrying an India-rubber flap at its lower end. The water was pumped out, the rock bored into, and another cylinder was slid inside the first and down into the excavation, and secured by cement. (Fig. 338 c.)

It was, however, found difficult to place the iron cylinder in position without first resorting to the

338 c.




338 d.



ordinary cribwork coffer-dam. The sinking of the shaft was commenced December 7, 1869. Only one man could work at a time, but in the space of 4 weeks a depth of 30 feet below low water was reached. Drifts were then run into the longer and shorter axes of the rock, and steam was used in hoisting. The rubbish was dumped upon one side of the rock, from which most of it was washed by the tide. During the month of January, 1870, 8 men found room to work. Most of the rock was removed by picks and sledges, only 10 lbs. of explosive (giant powder) being used in the whole operation. In February 16 men found space to work, and by the 20th of April the dimensions of the cavity were 140 by 60 feet, with a maximum height of 12 feet. Columns of rock were at first left for support, but they were from time to time replaced with upright timbers from 8 to 10 inches in diameter, with the exception of 4, which were left standing near the shaft. Preparations were now made to blow up the shell. Fig. 338 d, copied from the official report, will explain the method of conducting the explosion. Powder was used as the explosive, nitrate of soda taking the place of nitrate of potash in its composition. The quantity used was 43,000 lbs. The vessels for containing it were 38 ale-casks of 60 gallons each, and 7 old tanks made of boiler iron, holding about 300 lbs. of powder each. The explosion was effected by a galvanic battery stationed in a boat about 800 feet from the rock. A column of water about 200 feet in diameter was thrown into the air to a height of 200 to 300 feet, and pieces of rock and timber were thrown high above the water column. The rock was found to be effectually demolished.

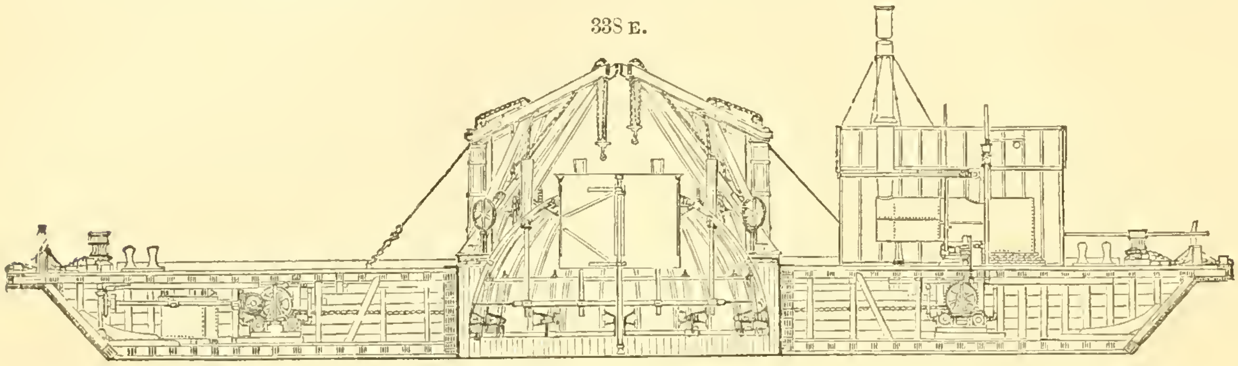
*The East River Improvement Works.*—The object of the works for the improvement of the East River was the removal of a mass of rocks that impeded the navigation from the Atlantic to New York by way of Long Island Sound, and were situated in the immediate vicinity of Hallett's Point, a promontory of Long Island. These obstructions consist of a number of sunken reefs and rocks well known as "Hell-Gate," which caused a rush of water through the pass, and which, taken in connection with the dangerous currents and surface agitation, have been a lively source of danger to navigation ever since ships came up the river.

In 1852 an appropriation of $20,000 was made, and work was commenced under the charge of Major Fraser, of the United States Corps of Engineers, upon one of the obstructions, known as Pot Rock. By means of sinking blasting charges on to the top of the rock, and firing them by batteries on the surface, the depth of water at this point was increased from 18.3 feet to 20.6 feet; the expense attending this operation having been $18,000.

The work stopped here for about 15 years, when some action was again taken in the matter, and General Newton, of the United States Engineers, reported on the obstructions in January, 1867. Upon this report appropriations were made, and operations were commenced at Hell-Gate. A scow was built specially adapted for drilling, Fig. 338 e, and towed over the rock in which it was desired

to form the holes. In the centre is an octagonal well 32 feet in diameter, in which is suspended a wrought-iron dome for protecting the divers. At the top of the dome is a telescope 12 feet in diameter, with a rise and fall of 6 feet, to adapt its height to the various stages of the tide. When the dome is in working position, it stands clear of the scow, resting on self-adjusting legs, which adapt

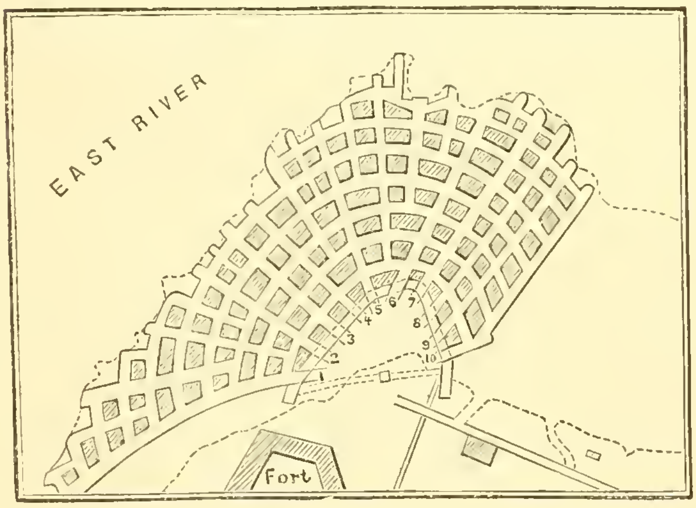
338 E.



themselves to the inequalities of the reef. The drilling engines, 9 in number, are supported by movable bridges, thrown back when the dome is up. The drill-bars work within stout iron tubes, passing through the dome, one at the centre, the others ranged in a circle about 20 feet in diameter. This machine was set to work in 1869, and considerable improvements were effected by it on two of the most formidable reefs.

In August, 1869, the first works were commenced for attacking the main body of obstructions at Hallett's Point, and a coffer-dam was formed upon the reef, where the rocks were bare at low water. It was built of heavy timbers bolted down to the rock. The coffer-dam was completed and pumped out the following October, and a shaft 33 ft. below low water was sunk. This part of the work was continued till June, 1870, when it was suspended for want of funds. At that time 484 yards of rock had been removed at a cost of \$5.75 a yard. In July, however, operations were resumed with vigor, the shaft was sunk to its full depth, the ten main radiating galleries were driven for lengths varying from 51 feet to 126 feet, and two of the cross-galleries were commenced. During 1870 no less than 8,306 cubic yards of rock were removed, the drilling having all been done by hand.

338 F.




In 1871 machine-drilling supplemented the slower and more costly handwork; 1,653 feet of main tunnel and 654 feet of connecting galleries were made, and 8,293 cubic yards of rock were taken out. The same year a careful survey of the reef was made to ascertain the exact contour of the rock, in order to regulate the operations beneath; more than 16,000 observations were recorded in connection with this part of the work. Fig. 338 F shows the general arrangement of the work. The form of the reef on the 25-foot water-line is indicated in dotted lines, and it will be seen that the main tunnels radiate from the sides of the shaft inclosed by the coffer-dams to the 25-foot water-line. Between these main tunnels 13 intermediate ones of greater or less extent were driven, and the whole series were connected by means of concentric galleries, approximating to the contour of the reef, which was, it will be seen, completely honeycombed, a roof being left of a thickness ranging from 6 feet to 16 feet, and supported on 172 columns. In order to prepare for the immense blast which was instantaneously to break up the shell of rock left, and open the passage to navigation, over 4,000 holes were drilled in the columns and roof to receive the charges, which were all connected together and brought to the discharging battery on shore. The holes were from 2 to 3 inches in diameter, about 10 feet apart, and the average depth was 9 feet; the proportions, however, varied with the nature of the rock and other circumstances. It should be mentioned that some difficulty was caused in drilling these holes by the increased amount of leakage produced by tapping seams; the maximum quantity of water pumped, however, did not exceed 500 gallons per minute. The following is a summary of the leading particulars of *matériel* used for the explosion:

| | Pounds. |
|---|---|
| Dynamite in tin cartridges | 24,812 |
| " paper " | 1,164 |
| " primers | 2,925 |
| Total weight of dynamite | 28,901 |
| "Rendrock" in cartridges | 9,061½ |
| "Vulcan" powder in cartridges | 14,244 |
| Total charge | 52,206½ |

| | Pounds. |
|---|---|
| Total number of cartridges | 13,596 |
| " " brass primers | 3,680 |
| " " holes with primers | 3,645 |
| Number of iron pipes with primers | 35 |
| Number of holes not charged | 782 |
| Total number of holes and pipes | 4,462 |
| | Feet. |
| Length of connecting wire | 100,000 |
| " leading wire | 120,000 |
| Number of cells in firing battery | 960 |

There were employed 12 firing batteries of 40 cells each, 4 of 43 cells, and 7 of 44 cells. The distance of the firing-point from the shaft was 650 yards.

The holes having been all charged and the connection with the batteries made, the workings were flooded by means of a 12-inch siphon on September 11, 1876; and on the 24th, with scarcely any perceptible tremor, and with a comparatively insignificant lifting of the water, the 50,000 lbs. of dynamite were exploded, and the work which had been so many years in progress was thus completed in a moment. The result was a depth of 12 feet at 180 feet from the shore, 16 feet from 180 to 300 feet, and 20 feet beyond 300 feet from shore, leaving about 30,000 cubic yards of rock to be dredged in order to complete the works. The estimate for completing the entire work of improving Hell-Gate and the East River was $5,139,120.

*Blasting in Coal-Mines and Soft Rock.*—Blasting in coal-mines where fire-damp is prevalent is often attended with great danger of explosion. Heavy blasts in soft rock are liable to cause extensive disintegration, and to imperil the safety of roofs and supports. Various devices are in use to rend rock without employing explosives. Messrs. Dubois and François employ a drill which may be adjusted to bore a hole in any given direction and at any height. The location of the first hole, drilled in the ordinary manner, is such that the least resistance is offered to the removal of the greatest body of rock. When its depth is sufficient, the drill-rod is taken out, and a mass of iron weighing from 60 to 80 lbs. is attached to the piston-rod in the same manner as the drill. A wedge and corresponding split bearing surfaces are inserted into the hole, and the drill worked as a hammer. In the Seraing pit (Belgium) a heading 277 feet long has been completed by this means in 405 shifts of 8 hours by two men.

Levet's system of needle-quoin, exhibited at the Paris Exposition, consists of a hydraulic cylinder which forces wedges upon a quoin previously inserted in the hole. The pump is worked by the miner. It is claimed that with a hole 3.2 inches in diameter this apparatus is capable of producing the effect caused by the explosion of 14 ounces of powder.

*Blasting with high explosives* offers the advantage that, owing to their great strength, the holes can be set either perpendicularly to the face—i. e., in the line of least resistance—or at a very acute angle, while black powder must be charged at an angle of 45° or less in firm, unfissured rock. In Europe this property has led to the holes in a narrow heading being set normal to the face with no bearing; and in this country, though holes normal to the face are not the rule, deeper holes are drilled at a less angle than could possibly be taken with black powder. The properties of these substances are discussed under EXPLOSIVES.

*Cost of Extraction by Blasting.*—To determine the cost of extraction, according to Drinker, multiply the days' wages of the miner (8 hours) by the coefficient 2.041 for rocks to be quarried and blasted, or by 3.903 for rocks to be blasted only in tunnel work. For open-cut work, in the first case multiply the wages by 0.65, and in the second by 1.04. This gives the cost per 35.31 cubic feet of excavation in tunneling and open-cut work respectively.

*Works of Reference.*—The reader is referred to General John Newton's annual reports to the Chief of Engineers, U. S. A., for 1873, 1874, 1875, and 1876, on "The Removal of Obstructions at Hell Gate," etc.; to a paper by Mr. Julius H. Striedinger on "The Simultaneous Ignition of Thousands of Mines," read before the American Society of Civil Engineers, April 4, 1877, in the Transactions of the Society, vol. vi., No. 162; *Scientific American*, xxxv., 214; and to the report of Major R. S. Williamson and Captain W. H. Heuer on "Removal of Blossom Rock, San Francisco Harbor." There are also a number of reports from other engineers in the U. S. service on submarine blasting; among them may be specially noted those of Mr. E. P. North and L. W. Schermerhorn. See also, for rules for blasting, etc., the following references: Gillespie, "Roads and Railroads," 10th ed., New York, 1871; *Civil Engineers' and Architects' Journal*, ii., 256 (1839); *Mechanics' Magazine*, xxxiii., 597 (1840); *London Mechanics' Magazine*, xlvi., 407, 455 (1847). For a very complete discussion of the theory and practice of blasting—from which the foregoing article is partly abridged *—see "Tunneling, Explosive Compounds, and Rock Drills," by H. S. Drinker, E. M., New York, 1878. See also "Rock Blasting," André, London, 1878. The following references may be consulted for records of heavy blasts: *Civil Engineers' and Architects' Journal*, vols. xxiv., xix., xv., vi., ix.; *Mechanics' Magazine*, xxxviii., lviii.; *The Builder*, viii.; *Iron*, vi.

BLOCKS. A block consists of one or more pulleys, called sheaves, which are generally formed of lignum-vitæ, or some hard wood, inserted between cheek-pieces, forming what is called the shell

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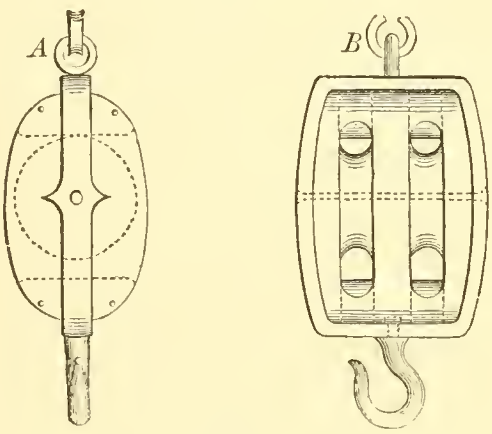
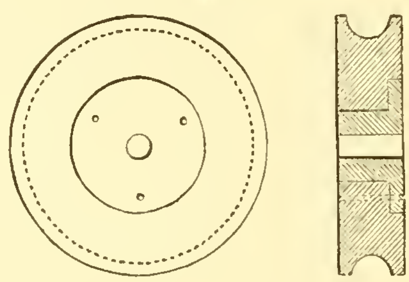
of the block, and turning upon a pin passing through the shell and the centres of the sheaves. Blocks are suspended by straps, either of rope or iron; the latter are called iron-strapped blocks, and have frequently a swivel-hook. A combination of two blocks, one of which is attached to the load to be raised, is called a tackle, and the power is to be estimated by the space through which the fall (which is that part of the rope to which the power is applied) passes, compared with the space through which the load is raised, deducting for friction, which is great, owing to the rigidity of the ropes and the small diameter of the sheaves; these, for nautical purposes, are necessarily limited by considerations as to weight and space. The grooves in the body of the block are called scores. The hole in the shell for the sheave pin or pintle is lined with bronze or gun-metal called a bushing. When the shell is made of one piece it is called a mortise-block; when more than one are employed it is termed a made block. The sides of the shell are cheeks. The groove in the sheave is termed the gorge. It has a bushing called a coak around the pintle hole. The space between the sheave and its block through which the rope runs is called the swallow, or channel. For strapping a block with rope in the common way, the rope is cut $1\frac{1}{2}$ time the circumference of the block. In many cases blocks are strapped with eyes or thimbles on the ends, or, instead of the loop, have a tail, as is the case with *Jigger-Blocks*—or, as they are commonly termed, *Tail-Blocks*. Blocks receive names from peculiarities of structure, from their materials, uses, mode of connection, etc. A block having a fixed position is called a *Standing-Block*, while one which is attached to the weight and hoisted with it is called a running-block. A *Snatch-Block* consists of a single sheave, with a notch cut through one side of the shell to allow the rope to be lifted in or out without inserting it end first. Fig. 339, *A B*, is a form of block in common use for shipping in this country. Its construction is easily understood from the figure. The block is double, or with two sheaves, and the shell consists of three large pieces with four pieces inserted between them at the top and bottom of the block. The whole is firmly bound with an iron strap. Figs. 340, 341, represent the construction of sheaves, with iron bushings,

339.




340.



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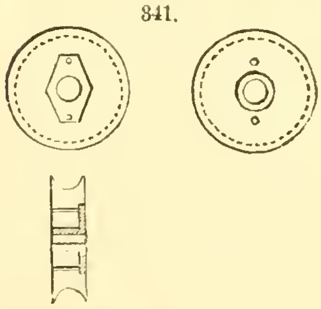

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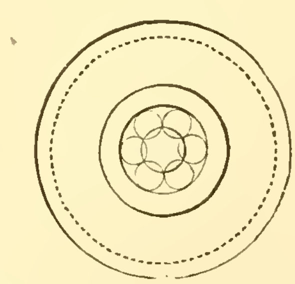


the collars and rivets being counter-sunk. Fig. 342 is an elevation of a sheave showing an arrangement of friction-pulleys or rolls, to admit of an easier motion.

*Bee-Blocks* are pieces of hard wood bolted to the sides of the bowsprit-head for reeving the fore-top-mast stays through.

There is a species of blocks termed "*Dead-Eyes*," which are used for tightening or setting up, as it is called, the standing rigging of ships. It consists merely of a circular block of wood, with a groove on its circumference, round which the lower end of the shroud, or an iron strap, is fastened; three holes passing through the face (ranged in a triangle), to receive the laniard, or smaller rope, which forms a species of tackle for tightening the shrouds. There are no sheaves in the dead-eye, but the edges of the holes are rounded off to prevent cutting the laniard; but this very imperfectly answers the purpose; as from the roughness of the grain of the wood, which is usually elm, and from the stiffness of the rope, the laniard renders with difficulty; and from the great strain to which it is subjected, it is frequently broken. A very simple and effectual improvement has been made in this respect, by inserting a half-sheave of lignum-vitæ into each of the holes, which causes the laniard to render with greater facility, and the shroud to be set up in half the usual time.

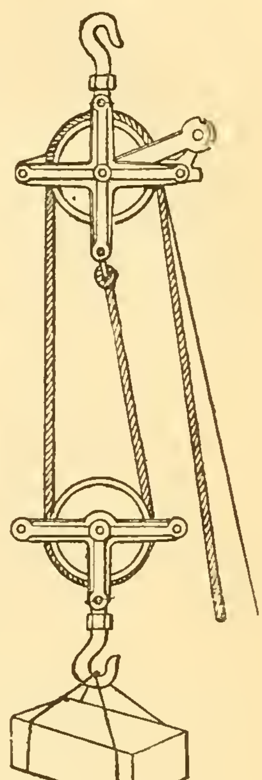
A *Double-Block* has two sheaves, which are usually placed on the same pin, but rotate on separate mortises in the shell. A *Euphroe* is a long slat of wood perforated for the passage of the awning-cords, which suspend the edge of an awning. A *Fiddle-Block* has two sheaves in shells of different sizes placed end to end.

*Differential Pulley-Block.*—The upper block of the tackle has two sheaves, one a little smaller than

the other, fastened together; they are, in fact, one piece. The grooves are furnished with ridges, which prevent the chain from slipping round them. The lower pulley consists of one sheave, which is also furnished with a groove. To this pulley the load is attached. The endless chain passes up from the hand over the large part of the sheave in the upper pulley, then down and under the lower pulley, then up over the small part of the sheave, and thence forms a bight to the hand. When the hand pulls the chain downward the two grooves of the upper pulley begin to turn together, so that the large portion winds up the chain while the smaller portion is lowering. By pulling on the chain, proceeding from the smaller part of the upper sheave, the chain is lowered by the large groove faster than it is raised by the small one, and the lower pulley descends. With the arrangement as shown in Fig. 343, a man is enabled to raise a weight about six times greater than he could raise without such assistance. With the Epicycloidal pulley-block two chains are used: one a slight, endless chain, to which the power is applied; the other, a short chain, which has a hook at each end, from either of which the load may be suspended. Each of these chains passes over a sheave in the block; these sheaves are connected by mechanism so contrived that, when the power causes the sheave over which the slight chain passes to revolve, the sheave which carries the large chain is also made to revolve, but very slowly. While the Differential pulley-block has a mechanical efficiency of 6, the Epicycloidal block has only a mechanical efficiency of 5.

343.

344.



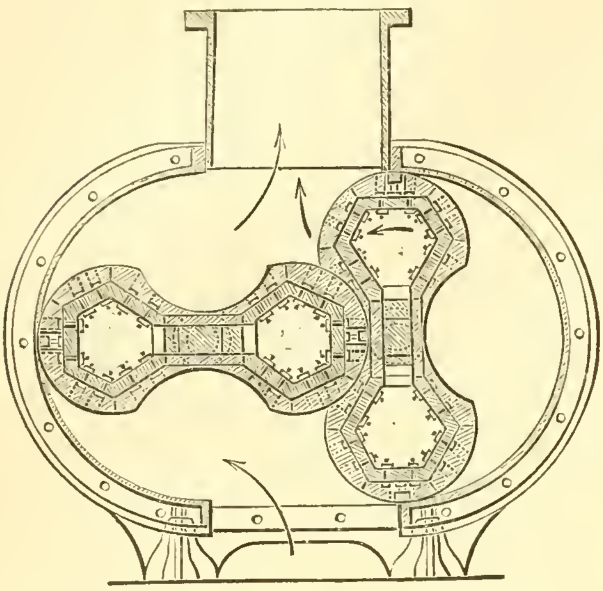
A self-stopping pulley-block is illustrated in Fig. 344. The rope, after being fastened to the bottom of the top pulley, is so passed round the pulley that the end to which the power is applied passes immediately under a brake-piece. To allow of the load being lowered, a cord is fastened to the brake, the load is slightly lifted, the cord is pulled, thus relieving the pulley-rope from the brake, when the load will descend of its own weight, care being taken not to let go the pulley-rope.

BLOWERS. Machines especially adapted to the creation of an air-blast. They are also employed for the converse purpose of exhausting air. Their application was at first mainly restricted to the supplying of blasts for furnaces for working metals and for steam-boilers. At the present time, the principal uses of the blower may be summarized as follows: To generate blasts for forges, and for all kinds of furnaces for the smelting, melting, heating, and converting metals and ores, or for like apparatus employed in the metal-working industries; to force the hot volatile products of combustion into kilns for drying fertilizers, brick, etc.; for blowing air heated by live or exhaust steam, or other means, under beds of wet wool and cotton, into machines for drying wet cloth and hosiery, or into receptacles for drying lumber or manufactured products, such as tubs, pails, etc., or tobacco, grain, vegetables, gunpowder, glue, chemicals, or leather in tanneries; to remove shavings, sawdust, etc., from wood-working machines; steam and vapor arising from paper-machines, and all drying cylinders and dry rooms; sweat from millstones; offensive odors from fat-rendering and dyeing establishments; dust from rag and cotton-pickers, flax and rope machinery; light impurities arising from the cleansing of grain; dust from grinding-rooms. Blowers are also used as exhausters in gas-works; to ventilate close, fetid places, as mines, wells, cisterns, holds of ships, etc.; to furnish a current of warmed, cooled, moistened, or medicated air, to public buildings and apartments liable to be closely occupied; to assist in evaporating fluids by removing the steam from the vicinity of the boiling sirup, or other solutions; to raise fluids on the principle of the Giffard injector, as in some of the ejectors used in oil-wells; to assist in the dispersion of liquids, as in atomizers; and to afford a current of air to be cooled by passing over ice, or artificially-cooled surfaces, as in meat-preserving chambers and in ice-machines; to furnish the suction or blast necessary to impel the carriages or boxes in pneumatic railroads or dispatch-pipes.

The three chief types of apparatus for generating air-blasts are: 1. The blowing-engine, wherein the blast is generated by pistons working in cylinders; 2. The rotary-force blast-blower, which operates also by the regular displacement of the air, measuring and forcing forward a definite quantity at each revolution; and 3. Fan-blowers wherein the current is produced by vanes revolving in a case or box. For blowing-engines, see AIR-COMPRESSORS.

*Rotary-Force Blast-Blowers.*—Root's blower, a section of which is given in Fig. 345, contains two rotating pistons, the curved edges of which mutually enter suitably-formed indentations in the sides. When the air enters the case at the induction opening, it is closed in by the pistons (or rather the wings) of the same, and is thus absolutely confined and forced forward as the pistons rotate, until brought to the eduction-pipe, where it is discharged. The system of construction and packing is such that there can be no backward escape of the air after it enters the case, the pistons being at all times in contact. Besides producing a positive force-blast, this machine operates effectively at a speed of 100 to 200 revolutions per minute. At the Cincinnati Industrial Exposition of 1871, the following tests were made of the Root blower, with the results noted: Diameter of pulley on line-shaft, 36 inches; width of belt, $5\frac{1}{2}$ inches; circumference of pulley, 9.425 feet; number of

345.



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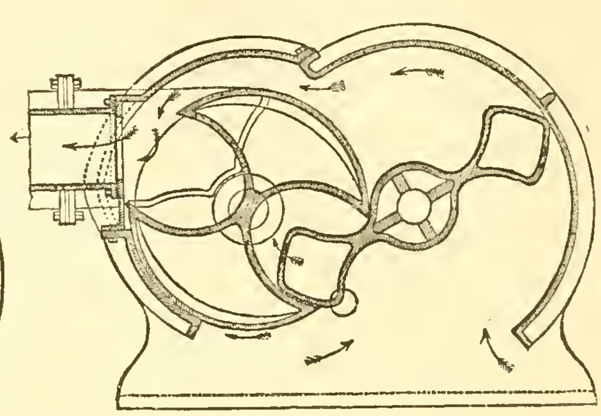


square feet of belt traveling over main pulley by each revolution, 4.32. The tension of the belt was regulated by cutting out one inch for every 10 feet of length, so that the belt had to stretch 1-120 of its length, after being laid over pulleys.

| TRIAL DATA. | First Test. | Second Test. | Third Test. | Fourth Test. |
|---|---|---|---|---|
| Number of revolutions of line shaft per minute | 200 | 200 | 152 ? | 100 |
| Number of revolutions of blower per minute | 200 | 200 | 152 | 100 |
| Diameter of nozzle in inches | $5\frac{1}{8}$ | 4 | $3\frac{1}{16}$ | 2 |
| Area of nozzle in square inches | 20.63 | 12.566 | 7.37 | 3.14 |
| Pressure of air above atmosphere in pounds per square inch | $\frac{1}{4}$ | $\frac{5}{8}$ | $1\frac{1}{8}$ | $1\frac{3}{4}$ |
| Volume of air delivered per minute in cubic feet (reduced to atmospheric pressure) | 1,155. | 1,112. | 8.84 | 465. |
| Volume of air delivered per revolution of blower in cubic feet (reduced to atmospheric pressure) | 5.775 | 5.56 | 5.81 ? | 4.65 |
| Volume of air delivered per 100 square feet of belt traveling over main pulley | 133. | 129. | — ? | 108. |

The belt slipped when the opening was closed. The volume is calculated from the following formula:

$$V = C \times \frac{A}{144} \times 60 \times \sqrt{2\,G \times 1{,}782\,P}.$$

$V$, volume delivered per minute in cubic feet. $G$, acceleration of gravity = 32.166. $C$, coefficient of contraction of nozzle used = 0.8. $A$, area of nozzle in square inches. $P$, pressure in lbs. per square inch. 1,782 = height of column of air of 1 square inch section weighing 1 lb.

The following table furnishes some interesting particulars as to the dimensions, work, dimension of discharge-pipes, and other details respecting Root's blowers:

*Particulars of Root's Rotary Blowers.*

| NUMBER OF BLOWER. | MELTING IRON. Number of Revolutions per Minute. | MELTING IRON. Tons of Metal per Hour. | MELTING IRON. Adapted to Cupola Inside Lining. | Approximate Horse-power. | Volumes of Blast in Cubic Feet delivered per Minute. | GENERAL DIMENSIONS. Diameter of Pulleys. | GENERAL DIMENSIONS. Breadth of Pulleys. | GENERAL DIMENSIONS. Diameter of Delivery Orifice. | EXTERNAL DIMENSIONS. Length. | EXTERNAL DIMENSIONS. Breadth. | EXTERNAL DIMENSIONS. Height. | Approximate Weights. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | In. | | | In. | In. | In. | Ft. In. | Ft. In. | Ft. In. | Cwts. |
| No. 2 A. | 330 | $2\frac{1}{2}$ | 24 to 30 | 2 | 1,650 | 14 | 5 | 8 | 3 10 | 3 0 | 2 6 | $8\frac{1}{4}$ |
| No. 2 | 400 | 3 | 24 " 30 | 2 | 2,000 | 12 | 4 | 8 | 4 8 | 3 0 | 2 6 | $9\frac{1}{2}$ |
| No. 3 | 350 | $4\frac{1}{2}$ | 30 " 36 | 4 | 3,000 | 14 | 5 | 10 | 5 8 | 3 0 | 2 8 | 12 |
| No. 4 | 325 | 8 | 36 " 48 | 6 | 4,550 | 16 | 6 | 12 | 6 8 | 4 0 | 3 4 | 18 |
| No. 5 | 320 | 12 | 48 " 60 | 8 | 6,400 | 18 | 7 | 14 | 7 10 | 4 0 | 3 6 | 23 |
| No. 6 | 310 | 16 | ........ | 11 | 8,650 | 20 | 9 | 18 | 8 0 | 5 0 | 4 0 | 30 |

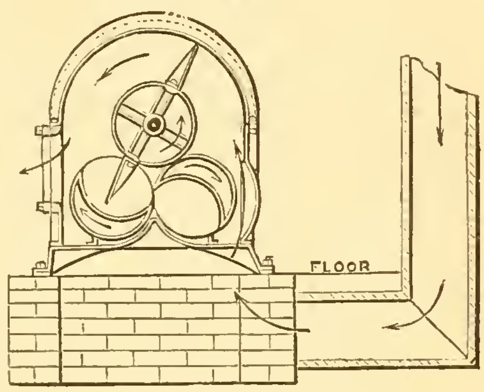
Blowers should be set on good solid stone foundations, to which they should be held by proper bolts, and care should be taken to set them level lengthwise. Iron piping for the air-conducting pipes should be provided, and these, with the shut-off valves and connections, should be perfectly tight. An escape-valve may be fixed upon the air-pipes, to relieve the blower from too great an increase of pressure of air, caused by the closing of the shut-off valves while the machine is in operation.

A section of Disston's rotary blower is given in Fig. 346. Within the case are two revolving bodies,

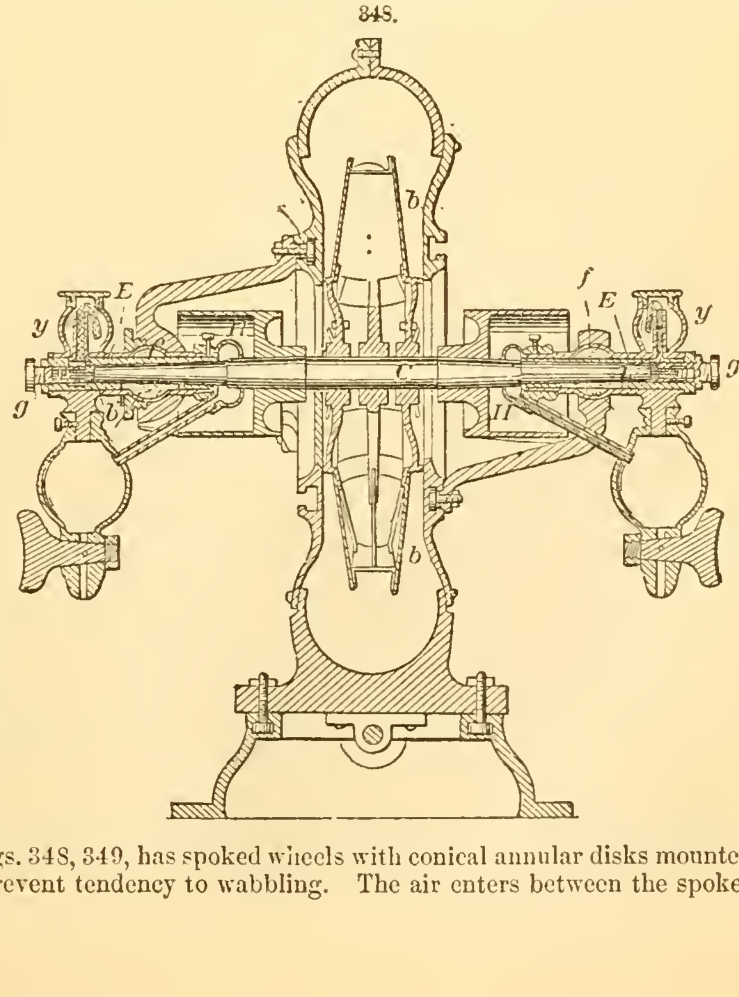
working together as shown, and geared by a pair of equal wheels at one end of their shafts, to insure conformity of motion. One of these bodies is a drum, turned on its outer circumference and at its ends to fit its part of the casing snugly, and having the hypocycloidal cavities opposite each other. The other revolving body, of a considerably larger diameter, is also of cast-iron, its central cylindrical part fitting against the outside of the drum; alternately, one of its blades works into the hypocycloidal cavities of the drum, while the other works against its side of the casting. This body might properly be called the piston, as it performs nearly all the work; only a small part of the air taken in by the cavities of the drum is forced into the delivery-passage when the blade of the piston enters the cavity. The blades of the piston are cored out, as seen in the section, and these cores have openings to the outside. When a blade begins to enter one of the cavities in the drum, its core is filled with compressed air, which afterward, when connection with the supply space is cut off, flows into the cavity of the drum, where the air, in consequence of the piston-blade passing out, is expanded. Before the piston-blade leaves the cavity of the drum entirely, its core comes opposite to openings in the heads of the casing, which allows either atmospheric air to enter, or any surplus air to escape, thus putting all these spaces in equilibrium.

The Baker rotary blower is represented in Fig. 347. The external case of the blower is made of cast-iron and bored out truly. The heads of the machine are also made of cast-iron and faced off, and firmly secured by bolts to a cast-iron bed-plate. The case is bolted and doweled between the two heads, which retains it in proper position. The drum concentric with the case, as well as the two lower drums, are each one solid casting, and are all turned and balanced as true as possible. The two lower drums only act as abutments alternately; the opening in their sides is to allow free passage of the vanes of the central drum. The gearing on the exterior of the blower is for the purpose only of retaining each drum in its proper position. The semi-annular space above the central drum is the chamber, from which the air is expelled by the vanes of the central drum in its revolutions. This space, as may be seen by the cut, is a section of a ring at all points of equal radius and area; and, as the vanes of the central drum continue to revolve at the same velocity, the air expelled must be in a continuous stream. One advantage in the internal movements of this blower is that each part is in a true circle; therefore, if the gears should wear, it will not affect the efficiency of the machine. At a test made of this machine by a committee of the Franklin Institute of Philadelphia, in 1875, the following results were obtained. Experiments conducted as to forcing capacity and tightness by applying pressure-gauges to a machine of the capacity of 12 cubic feet per revolution and by indicator-diagrams from a Rider engine: 1. Blower run for 5 hours at 150 revolutions per minute, equal to a displacement of 1,800 cubic feet per minute. A diagram taken at the beginning and end of the run, and air-pressure observed at like times. Found not to have varied. 2. Outlet of blower contracted to 9 square inches, and a pressure of 2 lbs. was shown in the manometer, with an indicated horse-power of 12.88.

347.




348.

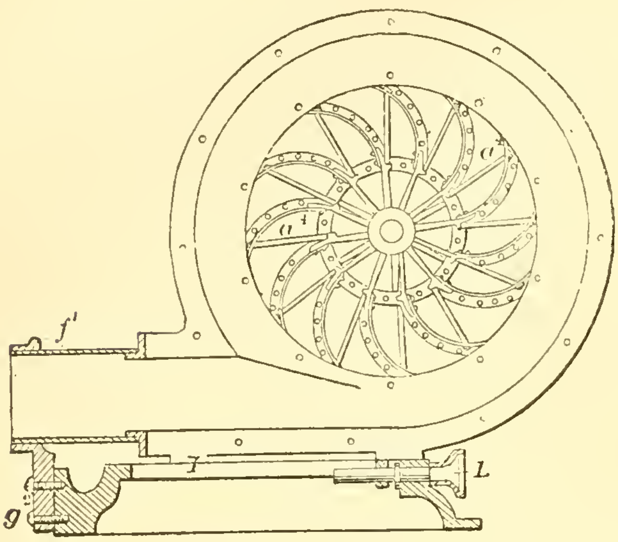



A repetition of this experiment five minutes later showed $1\frac{7}{8}$ lb. on manometer, with indicated horse-power of 13.95. A third experiment showed $1\frac{5}{16}$ lb. on manometer, with indicated horse-power of 14. The discharge-orifice was then closed, and the engine came to rest, after showing 3 lbs. on the manometer and indicating horse-power of 17.45. A further test was made by applying a sensitive pressure-gauge, and noting the fluctuation of pressure at different points in the revolution of the machine. Its variations were found to be greatest at low velocities, being from 15 to 18 per cent. of the pressure of the column of air discharged, the resistance on the driving-belt appearing to be nearly uniform throughout the rotation of the blower.

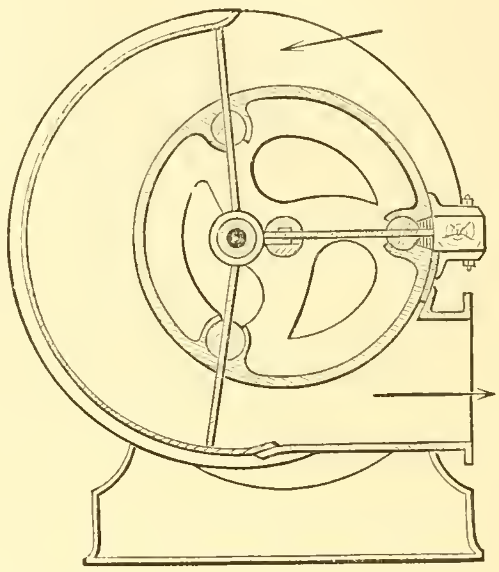
3. *Fans.*—Sturtevant's blower, Figs. 348, 349, has spoked wheels with conical annular disks mounted on an axis driven by two belts to prevent tendency to wabbling. The air enters between the spokes

round the axis, and is driven forcibly by the curved floats which span the space between the disks, being discharged into the peripheral chamber, whence it reaches the horizontal eduction-pipe, shown in the lower part of the figure. An oil-collector in each pulley gathers superfluous oil, and conducts the same to oil-chambers at the extremity of the shaft. Two machines of this description, used as exhaust-fans, and capable of removing 1,800,000 cubic feet of foul air per hour, are used for ventilating the Senate chamber and House of Representatives in Washington.

349.



350.



In the Mackenzie blower, Fig. 350, the fans are supported by a shaft, and caused to revolve by the revolutions of a cylinder contained in the shell. The fans are three in number, as will be seen by reference to the cross-section, loosely jointed to the shaft, and so arranged as to adapt themselves to a continuous alteration of the angle as they pass through the cylinder. The cylinder is hollow, and contains within it the fan-shaft. When the cylinder is in motion, the fans are caused gradually to project and gradually to recede beyond and beneath the line of its circumference, so as to conform accurately to the contour of the receptacle between the cylinder and the outer shell. The air is drawn in at the upper extremity in the direction of the arrow in the cut, and ejaculated from the lower extremity, as indicated by the outward-shooting arrow.

The following conclusions were reached after experiment by Mr. W. Buckle: "Having given the velocity of the air and the diameter of the fan, to ascertain the centrifugal force:

"*Rule.*—Divide the velocity by 4.01, and again divide the square of the quotient by the diameter of the fan. This last quotient multiplied by the weight of a cubic foot of air, at 60° Fahr., is equal to the force in ounces per square foot, which, divided by 144, is equal to the density of air per square inch.

"Or, substituting the following formula, we have $D = N \times .000034$. Where $D$ is the density of the air in ounces per square inch, and $N$ the number of revolutions of fan per minute, and $V$ the velocity of the tips of the fan in feet per second.

"Having given the density in inches of mercury (1 inch of which is equal to 8 oz. pressure), to find the velocity which a body would acquire in falling the height of a column of air equivalent to that density:

"*Rule.*—Multiply the density in inches of mercury by 930.3, and this product by 64. The square root of the last product will be the velocity in feet per second. Or, more simply—

"Multiply the square root of the density in inches of mercury by 244, and the product will be the velocity.

"It will be seen by the table that the velocity of the tips of the fan is practically somewhat less than this theoretical velocity, and from the experiments it further appears that the velocity of the tips of the fan is equal to nine-tenths of the velocity a body would acquire in falling the height of a homogeneous column of air equivalent to the density.

"Experiments were made as to the proper size of the inlet openings, and on the proper proportions to be given to the vane. The inlet openings in the sides of the fan-chest were contracted from $17\frac{1}{2}$, the original diameter, to 12 and 6 inches diameter, when the following results were obtained:

"First, that the power expended with the opening contracted to 12 inches diameter was as $2\frac{1}{3}$ to 1 compared with the opening of $17\frac{1}{2}$ inches diameter; the velocity of the fan being nearly the same, as also the quantity and density of air delivered.

"Second, that the power expended with the opening contracted to 6 inches diameter was as $2\frac{1}{2}$ to 1 compared with the opening of $17\frac{1}{2}$ inches diameter; the velocity of the fan being nearly the same, and also the area of the efflux pipe, but the density of the air decreased one-fourth.

"These experiments show that the inlet openings must be made of sufficient size, that the air may have a free and uninterrupted action in its passage to the blades of the fan, for if we impede this action we do so at the expense of power.

"With a vane 14 inches long, the tips of which revolve at the rate of 236.8 feet per second, air is condensed to 9.4 ounces per square inch above the pressure of the atmosphere, with a power of 9.6

horses; but a vane 8 inches long, the diameter at the tips being the same, and having, therefore, the same velocity, condenses air to 6 ounces per square inch only, and takes 12 horse-power.

"Thus, the density of the latter is little better than six-tenths of the former, while the power absorbed is nearly 1.25 to 1. Although the velocity of the tips of the vanes is the same in each case, the velocities of the heels of the respective blades are very different; for, while the tips of the blades in each case move at the rate of 236.8 feet per second, the heels of the 14-inch blades move at the rate of 90.8 feet per second; and the heels of the 8-inch move at the rate of 151.75 feet per second; or, the velocity of the heels of the 14-inch moves in the ratio of 1 to 1.67, compared with the heel of the 8-inch blade. The longer blade, approaching nearer the centre, strikes the air with less velocity, and allows it to enter on the blade with greater freedom, and with considerable less force than the shorter one. The inference is, that the short blade must take more power at the same time that it accumulates a less quantity of the air.

"These experiments lead me to conclude that the length of the vane demands as great a consideration as the proper diameter of the inlet opening. If there were no other object in view, it would be useless to make the vanes of the fan of a greater width than the inlet opening can freely supply. On the proportion of the length and width of the vane, and the diameter of the inlet opening, rest the three most important points, viz., *quantity*, and *density* of air, and expenditure of *power*.

"In the 14-inch blade the tip has a velocity 2.6 times greater than the heel; or, by the laws of centrifugal force, the air will have a density 2.6 times greater at the tip of the blade than that at the heel. The air cannot enter on the heel with a density higher than that of the atmosphere; but in its passage along the vanes, it becomes compressed in proportion to its centrifugal force. The greater the length of vane, the greater will be the difference of the centrifugal force between the heel and the tip of the blade; consequently, the greater the density of the air.

"Reasoning, then, from these experiments, I recommend, for easy reference, the following proportions for the construction of the fan:

"Let the width of the vanes be one-fourth of the diameter.

"Let the diameter of the inlet openings in the sides of the fan-chest be one-half the diameter of the fan.

"And let the length of the vanes be one-fourth of the diameter of the fan.

"In adopting this mode of construction, the area of the inlet openings in the sides of the fan-chest will be the same as the circumference of the heel of the blade, multiplied by its width; or the same area as the space described by the heel of the blade.

"The following table gives the sizes of fans varying from 3 to 6 feet diameter:

TABLE OF BEST PROPORTIONS OF FANS.

| Diameter of Fan. | | Width of Vane. | | Length of Vane. | | Diameter of inlet opening. | |
|---|---|---|---|---|---|---|---|
| ft. | in. | ft. | in. | ft. | in. | ft. | in. |
| 3 | 0 | 0 | 9 | 0 | 9 | 1 | 6 |
| 3 | 6 | 0 | 10½ | 0 | 10½ | 1 | 9 |
| 4 | 0 | 1 | 0 | 1 | 0 | 2 | 0 |
| 4 | 6 | 1 | 1½ | 1 | 1½ | 2 | 3 |
| 5 | 0 | 1 | 3 | 1 | 3 | 2 | 6 |
| 6 | 0 | 1 | 6 | 1 | 6 | 3 | 0 |

"I recommend the proportions in the above table for density ranging from 3 to 6 oz. per square inch; and for higher densities, viz., from 6 to 9, or more oz., the sizes given in the following table:

| Diameter of Fan. | | Width of Vane. | | Length of Vane. | | Diameter of inlet opening. | |
|---|---|---|---|---|---|---|---|
| ft. | in. | ft. | in. | ft. | in. | ft. | in. |
| 3 | 0 | 0 | 7 | 1 | 0 | 1 | 0 |
| 3 | 6 | 0 | 8½ | 1 | 1½ | 1 | 3 |
| 4 | 0 | 0 | 9½ | 1 | 3½ | 1 | 6 |
| 4 | 6 | 0 | 10½ | 1 | 4½ | 1 | 9 |
| 5 | 0 | 1 | 0 | 1 | 6 | 2 | 0 |
| 6 | 0 | 1 | 2 | 1 | 10 | 2 | 4 |

"The dimensions of the above tables are not laid down as prescribed limits, but as approximations obtained from the best results in practice.

"Experiments were also made with reference to the admission of air into the transit or outlet pipe. By a slide the width of the opening into this pipe was varied from 12 to 4 inches. The object of this was to proportion the opening to the quantity of air required, and thereby to lessen the power necessary to drive the fan. It was found that the less this opening is made, provided we produce sufficient blast, the less noise will proceed from the fan; and by making the tops of this opening level with the tips of the vane, the column of air has little or no reaction on the vanes.

"As to the pressure of the blast commonly required in smithies, the range is from 4 to 5 oz. per square inch. And an ordinary eccentrically placed fan, 4 feet diameter—the blades 10 inches wide and 14 inches long, and making 870 revolutions per minute—will supply air at a density of 4 oz. per square inch to 40 tuyères, each being 1⅝-inch diameter, without any falling off in density."

The following table* gives particulars of some experiments made with a large fan used to blow the cupolas, etc., at the London Works, Birmingham, England. Although in the early experiments only 36 to 50 per cent. of useful effect was reached, eventually as much as 75.16 was obtained. No

* From "A Practical Treatise on Casting and Founding," by E. Spretson (London, 1878).

allowance was made for obstruction in the fire, but the area of the tuyeres was taken, having taper pipes leading to them, and the velocity of the air, multiplied by the pressure, was taken to represent useful effect in horse-power.

*Results of Experiments with Common Fans.*

| NO. AND SIZE OF BLADES. | Revolutions of Engine per Minute. | Revolutions of Fan per Minute. | Velocity of Tips of Blades. | Theoretical Velocity of the Air in Feet per Minute. | Pressure of Blast in Inches of Water. | Diameter of Fan-tips of Blades in Feet and Inches. | Area of One Blade in Square Inches. | Area of Discharge. | Total Power of Engines. | Friction, etc. | Power Absorbed by Fan and Counter-Shaft. | Weight and Velocity of Air delivered, H. P. | Percentage Useful Effect. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 6 Blades, with centre plate, 16 × 8 | 25 | 712.5 | 12312 | 11358 | 8⅝ | 5 6 | 128 | 128 | 64.31 | 26.7 | 37.6 | 13.6 | 36.1 |
| | .. | ...... | ..... | 9954 | 6⅝ | .... | ... | 354 | 74.5 | ..... | 47.7 | 25.8 | 54. |
| 4 Blades, 16 × 12.. | 20 | 514.28 | 8818.9 | 7740 | 4 | 5 5½ | 192 | 194 | 41. | 22.38 | 18.56 | 6.9 | 37.17 |
| | 22½ | 578.57 | 9921.2 | 8646 | 5 | .... | ... | ... | 48.4 | 25.66 | 22.78 | 9.63 | 42.26 |
| 4 Blades, 16 × 8... | 25 | 712.5 | 12312 | 9678 | 6 | 5 6 | 128 | 354 | 63.5 | 28.7 | 34.8 | 23.37 | 67.1 |
| | .. | ...... | ..... | 10938 | 8¼ | .... | ... | 128 | 51.6 | ..... | 22.9 | 12.23 | 53.4 |
| 4 Blades, 18¼ × 12. | .. | ...... | 11192 | 10235 | 7 | 5 0 | 219 | 220 | 51.2 | 26. | 25.28 | 17.22 | 68.0 |
| | .. | ...... | .... | 10928 | 8 | .... | ... | 157 | 47.5 | ..... | 27.5 | 15.00 | 70.1 |
| | .. | ...... | ... | 9858 | 6½ | .... | ... | 354 | 55.8 | 22.1 | 33.73 | 24.78 | 73.4 |
| 4 Blades, 18¼ × 10. | .. | ...... | .... | 10500 | 7⅝ | 5 0 | 182.5 | 182 | 51.8 | 27.6 | 24.2 | 15.25 | 63.0 |
| | .. | ...... | .... | 9474 | 6 | .... | ... | 354 | 58.2 | ..... | 30.7 | 21.99 | 71.6 |
| 4 Blades, 16 × 12.. | .. | ...... | .... | 10235 | 7 | .... | 192 | 194 | 51.2 | 27.33 | 24. | 15.18 | 63.5 |
| | .. | ...... | ... | 9377 | 7⅞ | .... | ... | 354 | 56 1 | ..... | 28.76 | 21.31 | 74.1 |
| 4 Blades, 17 × 12.. | .. | ...... | .... | 10235 | 7 | .... | 204 | 204 | 51. | 27.7 | 23.25 | 15.97 | 68.68 |
| | .. | ...... | .... | 9474 | 6 | .... | ... | 194 | 57. | ..... | 29.1 | 21.9 | 74.2 |
| 4 Blades, 16 × 11.. | .. | ...... | .... | 10140 | 6⅞ | .... | 176 | 180 | 50. | 28.34 | 21.5 | 13.7 | 63.8 |
| | .. | ...... | .... | 9173 | 5⅝ | .... | ... | 354 | 54.7 | ..... | 26.41 | 19.97 | 75.16 |

A considerable difference in the amount of useful effect was sometimes produced by the same power; but this arose either from a difference in the area of opening or in the pressure. When the pressure was great, the result was generally affected, it being easier to get a moderate pressure with a fan than a high one. A 7-inch column of water is considered ample for cupolas. In all cases indicator figures were taken in order to arrive at the power employed, and figures were also taken separately without the fan, in order to get at the friction of the engine and shafting. The fan-case was an arithmetical spiral, so that the blades delivered the air regularly. The following rules were deduced from the experiments:

That the fan-case should be an arithmetical spiral to the extent of the depth of the blade at least.

The diameter of the tips of the blades should be about double the diameter of the hole in the centre; the width to be about two-thirds of the radius of the tips of the blades. The velocity of the tips of the blades should be rather more than the velocity due to the air at the pressure required, say one-eighth more velocity.

In some cases, two fans mounted on one shaft would be more useful than one wide one, as in such an arrangement twice the area of inlet opening is obtained as compared with a single wide fan. Such an arrangement may be adopted where occasionally half the full quantity of air is required, as one of them may be put out of gear, thus saving power.

Fans are less expensive in first cost and repairs, for a given duty, than blowing-engines; but when high pressures are required, they take somewhat more power to drive them. In other words, the fan is not an economical machine, in the sense of useful effect for a certain power; and its useful effect or "duty" decreases rapidly as the speed is increased for the purpose of increasing the pressure of blast. The power for driving a fan or fans is generally best given by a small high-pressure engine, communicated by a belt.

The engine should run at a quick speed, and be provided with a tolerably heavy fly-wheel, to prevent its running away in case of any accident to the driving-belt or fan. In order to get an increase of speed from the engine, the fly-wheel may be driven by a sun-and-planet motion instead of a crank; this will give two revolutions of the fly-wheel shaft for each double stroke of the piston, and then, with a large pulley on the fly-wheel shaft, and a small one on the fan-axle, a high speed can be obtained. But for many reasons it is unadvisable to use the sun-and-planet motion, if it can possibly be avoided. If a large volume of blast is required at a moderate speed, this can best be obtained by employing a fan of large diameter, driven at a moderate speed; but where a high pressure or great velocity of blast is desired, it is necessary to drive the fan rapidly.

It is not advisable to construct a fan larger than 8 feet in diameter, and for most ordinary purposes one of about 5 feet diameter across the vanes is to be preferred.

A silent fan can only be obtained by having vanes which do not fill the casing, having the vanes placed eccentrically in the casing, and forming the casing in a true spiral.

Provide ample apertures for the entrance and exit of the air, avoid sharp turns or projections in the casings, and, in designing and fitting up the fan, all the moving parts must be securely fixed in position, so that they will be able to withstand the great centrifugal force brought on them when driven at a high speed, as, if any part becomes detached during working, great damage and probable loss of life would ensue.

Fans, especially when large and driven at a high speed, should be walled in all round, and every precaution adopted to avoid loss of life, in case of any accident occurring to the fan while it is in motion. The castings for fans should be made massive, as tending to reduce the vibration felt when fans are worked at a high speed.

In fan-machinery, simple as it is, it has been found that monthly and even weekly repairs have been incurred, in consequence of the want of exact balance among the parts of the fan upon its

axle. With careful management in the first construction, this source of annoyance may be entirely removed. Another great fault consists of injudicious methods of "bringing up the speed" with too great rapidity, with a view to which it was certainly necessary to make use of as few intermediate shafts as possible, which of course requires that large pulleys shall drive proportionally smaller pulleys than if the rate of the reduction of speed were more moderate. On the other hand, the experience of many founders proves that by moderately attaining the speed by the use of a greater number of intermediate belt-pulleys, repairs of any importance are not incurred for months and even years. The great evil of too rapidly raising the speed is the liability of the belt to slip upon the drums; for when slipping occurs, especially among the slower parts of the motion, the belt is subjected to sudden and violent strains, caused by its unequal hold upon the rim of the drum. The usual remedy for this state of things is to apply rosin and pitch to the acting surface of the belt to give it a hold. But the best plan is to employ spur-gear in the slower parts of the motion, and broad belts and pulleys of conveniently large diameters for the rest.

The following notes on the construction of fans will be found of practical utility:

*Good Proportions.*—Inlet = $\frac{1}{2}$ diameter of fan. Blades = $\frac{1}{4}$ diameter of fan each way. Outlet = area of blades. The area of tuyeres is best when about = $\dfrac{\text{area of blades}}{\text{density of blast, oz. per sq. in.}}$; and it should not exceed twice this area.

The velocity of the circumference for different densities of blast is as follows, in feet per second and ounces per inch: 170, 3; 180, 4; 195, 5; 205, 6; 215, 7. A proper speed for cupolas is 250 to 300 feet per second.

*To find the Horse-power required for a Fan.*—D = density of blast in ounces per inch. A = area of discharge at tuyeres in square inches. V = velocity of circumference in feet per second.

$$\frac{\frac{V^2}{1000} \times D \times A}{963} = \text{horse-power required.}$$

*To find the Density to be obtained with a given Fan.*—$d$ = diameter of fan in feet.

$$\frac{\left(\frac{V}{4}\right)^2}{120 \times d} = \text{density of blast in ounces per inch.}$$

*Table showing Density of Blast.*

| Velocity of Circumference. Feet per Second. | Area of Nozzles. | Density of Blast. Oz. per Inch. |
|---|---|---|
| 150 | Twice area of blades | 1 |
| " | Equal " | 2 |
| " | ½ " | 3 |
| 170 | ¼ " | 4 |
| 200 | ½ " | 4 |
| " | ⅙ " | 6 |
| 220 | ½ " | 6 |

*Table showing the quantity of Air, of a given Density, delivered by a Fan. Total area nozzles in square feet × velocity in feet per minute, corresponding to density (see table) = air delivered in cubic feet per minute.*

| Density. Oz. per Square Inch. | Velocity. Feet per Minute. | Density. Oz. per Square Inch. | Velocity. Feet per Minute. | Density. Lbs. per Square Inch. | Velocity. Feet per Minute. | Density. Lbs. per Square Inch. | Velocity. Feet per Minute. |
|---|---|---|---|---|---|---|---|
| 1 | 5,090 | 7 | 13,200 | 1 | 20,000 | 6 | 49,000 |
| 2 | 7,000 | 8 | 14.150 | 1½ | 24.500 | 8 | 56.600 |
| 3 | 8.600 | 9 | 15.000 | 2 | 28,300 | 10 | 63.200 |
| 4 | 10.000 | 10 | 15.800 | 2½ | 31.600 | 12 | 69,280 |
| 5 | 11.000 | 11 | 16.500 | 3 | 34.640 | 15 | 78,000 |
| 6 | 12,250 | 12 | 17,300 | 4 | 40,000 | 20 | 89,400 |

*Competitive Tests.*—The pressure-blower has an advantage over the fan in its delivery of a positive or force blast measuring accurately the amount of air delivered per revolution. The blast does not depend, as in the fan, upon centrifugal action, nor upon the specific gravity of the air, to give a definite displacement. When the proper amount of air is supplied the combustion in a cupola furnace is perfect, and the highest rate of melting attained; but as the carbon converts the oxygen of the air into carbonic acid on its entrance at the tuyeres, so this compound is rapidly reconverted into carbonic oxide as it ascends through the charge. In order to secure the highest temperature and efficiency, enough of this oxygen must be continuously injected to prevent the formation of carbonic oxide, and this can only be done by a machine which delivers positively under all conditions of the furnace a fixed quantity. In conducting competitive tests between pressure-blowers and fans, the following formulæ and arrangements have been employed: Both blowers were placed so that they could be driven from one and the same shaft, to which the dynamometer was applied. The number of revolutions of the dynamometer-shaft was counted by an apparatus expressly built for the purpose. Each blower was provided with dovetail guides, to which four different slides were fitted, air-

tight. These slides, containing the discharge-openings of 6, $4\frac{1}{2}$, $3\frac{1}{2}$, and $2\frac{1}{2}$ inches diameter, respectively, were made of 1-inch thickness, and fitted to each blower. The pressure of the air was measured by a water-column, attached in such a manner and at such a place as to be affected properly by the pressure. The motive power was supplied by an overshot water-wheel, the gate of which could be moved at a place in the experimenting-room, where the pressure-gauge could be observed.

The manner in which the tests were made was the following: After the slide with the discharge-opening was attached, the speed was regulated so that the water-gauge indicated the pressure required. While the water-column was carefully kept at the same height, the indications of the dynamometer were read off and noted. Experiments of this kind were made with each blower, and conducted with openings ranging from 6 to $2\frac{1}{2}$ inches, and corresponding pressures from 4 to 16 ounces. It is evident that, through the same opening and at the same pressure, an equal volume of air would be discharged by either the blower or the fan. It is also evident that the horse-power indicated by the dynamometer, under the above conditions, would demonstrate the relative power required by each blower to produce a given result, and show the comparative efficiency of each machine.

The volume of air discharged per minute was calculated from the formulæ:

$$V = c. \frac{A}{144} 60 \sqrt{2\,g\,h}. \quad V = c. \frac{A}{144} 60 \sqrt{64.32 \times 1{,}782\,p}. \quad V = 140\,c.\,A. \sqrt{p}.$$

In which $V$, the volume of air discharged per minute in cubic feet, reduced to atmospheric pressure 29.9 barometer, and a temperature near freezing-point. $A$, the area of discharge-opening in square inches. $g$, acceleration of gravity $= 32.16$. $h$, height of column of air of one square inch in section, and of a temperature near freezing-point, weighing $p$—pounds—in feet. $p$, pressure of air in pounds per square inch. $c$, coefficient of efflux, depending on the shape of the discharge-opening, and due to contraction and friction. This coefficient was estimated by interpolation of the values given by Prof. F. Weisbach. $c. = 0.6$.

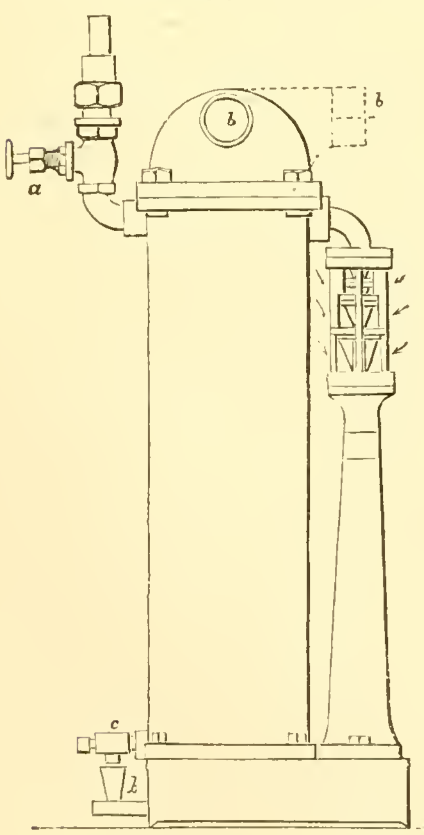
The useful effect, or the work done, was assumed to consist in giving the velocity $\sqrt{2\,g\,h}$ to the air discharged, and was calculated from the formulæ, viz.:

Useful effect in horse-power: $H = c.\,p.\,A \frac{1}{550} \sqrt{2\,g\,h} = \frac{144}{33{,}000}\,p\,V = \frac{1}{229\frac{1}{6}}\,p\,V.$

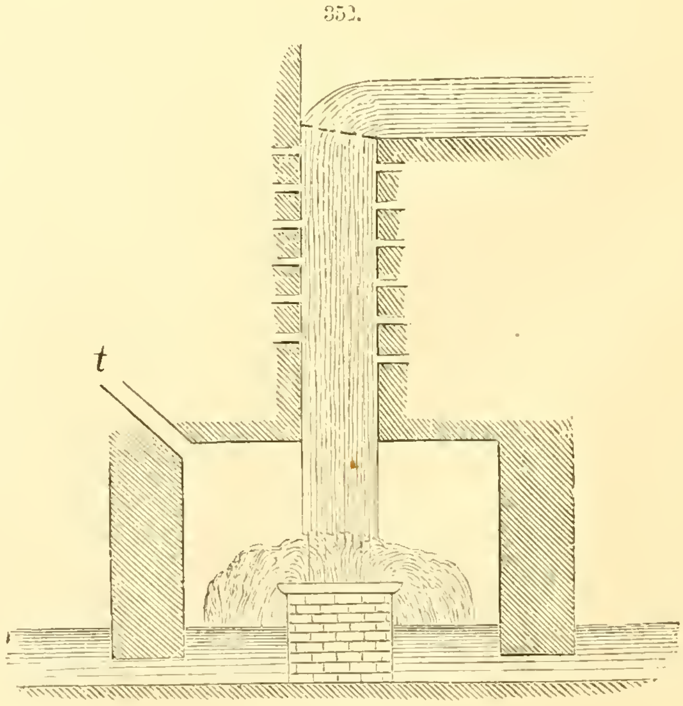
*Example:* Test No. 1: Pressure of air in pounds $= \frac{4}{16} = \frac{1}{4} = p.$ $\sqrt{p} = \sqrt{\frac{1}{4}} = \frac{1}{2}$. Area of discharge-opening in square inches $= 28.274 = A.$ $c. = 0.6.$ Volume of air discharged per minute in cubic feet $= V = 140\,c.\,A\sqrt{p} = 140 \times .6 \times 28.274 \times \frac{1}{2} = 1{,}186$ cubic feet. Useful effect in horse-power: $H = \frac{p\,V}{229\frac{1}{6}} = \frac{\frac{1}{4} \times 1{,}186}{229\frac{1}{6}} = 1.294.$

Various Forms of Blowers.—Fig. 351 represents a steam-blower devised by E. Körting. It consists, its principal parts, of an air-accumulator formed of a cast-iron tube opening below into a reser-

351.




352.




voir, which serves at the same time as a base-plate. At its upper extremity the accumulator supports a dome, into which is fitted the blast-pipe $b$, the nozzle of which is adapted to the opening into

the smithy fire. Immediately below this dome the steam-pipe traverses the accumulator with an exit at the opposite end, as shown. At this end is the aspirator, formed of three cones, which admit air in their interspaces, while the steam-jet is driven through the centre. The steam-loaded air passes through a conical eduction-pipe into the reservoir, which serves as a base-plate, where the water of condensation is parted with, and the heated current of air passes into the accumulator under a tension corresponding to the dimensions of the aspirator multiplied by the pressure of steam. From the accumulator the blast passes through the nose-pipe at *b* to the smithy fire. In this manner a blast is obtained, easily kept at any pressure, within certain limits, and at a temperature which very nearly reaches that of the steam used. In the engraving, *a* is the steam inlet; *b*, the blast-pipe opening from the accumulator; *c* and *d*, outlets for water of condensation.

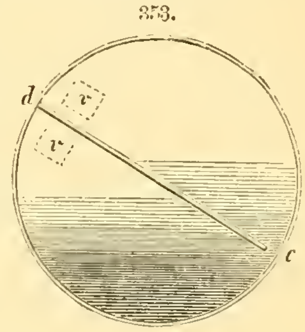
For other blowing-apparatus, see Air-Compressors.

A simple form of blower is the *Trompe*, or *Water-Blast*, of which Fig. 352 shows the principle.

In this, a vertical tube of wood or iron, cylindrical or prismatic, of length and diameter suited to the fall and quantity of water intended to be used, connects with a cistern below, made air-tight except for the opening *t*, to connect with the tuyère. Through this tube a stream of water is allowed to fall, drawing in the air as it descends through openings that are indicated by broken lines in the sides of the column, and breaking upon an altar below. The air thus carried into the cistern has no means of escape except the tuyère *t*, and its quantity and pressure delivered through that depends upon the absolute size of the column of water, and the proportions of the various parts. Venturi has already satisfactorily investigated the relations of this machine, which will not be dwelt on in that aspect further here than to say that, although very cheap and convenient in its construction, it uses more water for a given effect than a water-wheel would do, and that its effectiveness is quite limited. Karsten refuses to admit that the *dampness* of the blast it affords injures the quality of the iron; although it is probable that most metallurgists would conclude, in the face of general theory and experience, that the good quality of iron made by this method exists *in spite of it.*

The *Oscillating Cylinders* of D'Aubuisson are cheap to construct, and worked with little power and at small expense. Although not giving a blast of sufficient amount of density for the smallest high-furnace, except with the most fusible materials, they answer very well for chafery and finery fires. Fig. 353, which is a section of one of the cylinders, will afford an illustration of their action. A diaphragm, central, through the entire length and nearly the whole diameter, is shown at *c d*; *v v* are two valves, alternately aspiring and expiring. In its normal position *c d* is vertical; the barrel is filled half full of water, through a bung, and is then set in oscillation, through an arc of 90 or 100 degrees, by a connecting-rod and crank geared on near *c*. It is manifest that in different angular positions of the diaphragm the content of water in the two semi-cylinders will come to be unequal, as shown by the shaded lines; and the air will be respectively rarefied and condensed accordingly.

353.




BOILERS, STEAM. The steam-boiler is a close vessel used for the generation of steam from water. It has a furnace for the combustion of fuel—either inclosed within the boiler, as, for instance, in locomotive and the majority of marine boilers; external, as in the case of land-boilers set in brick-work; or detached, the latter form of furnace being often used for the combustion of tan-bark, sawdust, and similar substances. Boilers are constructed of cast and wrought iron, steel, and copper. Where wrought-iron, steel, or copper sheets are used in the construction, they are ordinarily fastened together with rivets, and the joints are made tight by calking; but in some instances the sheets are welded together, this last mode of construction having been recently introduced. Boilers may be either plain cylinders, or they may contain flues or tubes, so as to bring the water into more intimate connection with the flames and heated gases issuing from the furnace. Until a recent period, nearly all boilers, whatever their internal arrangement, contained inclosing-shells, as an essential part of their construction. Of late years, however, what are known as sectional or water-tube boilers have been introduced to a considerable extent. In this class of boiler, there are a number of connected sections, each of which is quite small, and the inclosing-shell is not used. Hence the several parts can be made light as well as strong; and it is claimed by some that an explosion of a single section of such a boiler would be less disastrous than the explosion of a shell-boiler.

It is not possible, in the limits of the present article, to give a complete treatise on this important subject, but the reader will find numerous references that will be of assistance in a more extended research.

*Combustion and Fuel.*—Combustion, in the popular acceptation, is the union of carbon or hydrogen with oxygen, accompanied by light and heat. Though this definition is far from being scientifically exact, the word can be used in this sense without impropriety, in treating of the combustion of fuel. Some forms of fuel, it is true, contain sulphur, which also unites with oxygen during combustion, but the proportion of this latter element is usually quite small, and its heating effect can be neglected without serious error. The sulphur in coal is, however, occasionally injurious to the fire-box of a boiler. The chief constituents of fuel are carbon, hydrogen, oxygen, compounds of these elements, and earthy matter. The principal varieties of fuel are wood, peat, coal (which may be divided into lignite, bituminous, and anthracite), mineral oil, natural gas, sawdust, spent tan, straw, and other refuse. There is generally some special arrangement of the furnace and proportions of boiler that are best adapted for each form of fuel, as is explained more fully in another part of this article.

The reader who desires to thoroughly investigate the qualities of the chief varieties of fuel will find a valuable collection of data in Dr. Percy's "Treatise on Metallurgy." The remarks in the present article must necessarily be confined principally to coal, the fuel in common use.

Mineral oil, when burned under proper conditions, is one of the most efficient forms of fuel, in some cases about nine-tenths of its full calorific effect being utilized. An ordinary furnace can be readily adapted to its use. An improved process for burning liquid fuel is described in the *Engineering and Mining Journal*, August 7, 1875.

In localities where natural gas is obtained, this is frequently burned in the furnaces of boilers.

*Peat.*—Peat is used in this country as fuel to a very limited extent. In Europe its applications have been numerous, and a large amount of capital is invested in plant for its preparation, which consists, generally, in drying and compressing it. Considerable information in regard to the preparation and qualities of this form of fuel is to be found in "Peat and its Uses," by S. W. Johnson; "Report on the Utilization of Peat and Peat Lands," by F. A. Paget (in the "British Reports on the Vienna Exhibition," and *The Engineer*, xxxix., xl.); in the "Proceedings of the Institution of Civil Engineers," xxxviii.; in the "Proceedings of the Institution of Mechanical Engineers," August, 1865, and the "Transactions of the Society of Engineers," 1864.

*Coal.*—The fuel most commonly employed in this country is coal, and some little space will be devoted to a consideration of the phenomena of its combustion. If a mass of coal is brought to a sufficiently high temperature (probably 1,000° Fahr.), the combustible materials enter into combination. First, the water is expelled; then the hydrogen in the volatile combustible matter unites with oxygen, forming water; and the carbon set free unites with oxygen, forming carbonic acid if the temperature is sufficiently high and enough oxygen is present, or, under less favorable circumstances, forming carbonic oxide, or passing off unconsumed, as the coloring matter of black smoke, and being deposited as soot. The combustion of the fixed carbon next begins, and usually takes place as follows: The first combination of the carbon with oxygen produces carbonic acid, which, in passing through the bed of coal in the furnace, frequently takes up more carbon, and is converted into carbonic oxide. If it is allowed to pass away in this state, there is a considerable loss of heat, as carbonic oxide is a combustible gas. By furnishing additional oxygen, however, this carbonic oxide will be burned, or converted into carbonic acid, in the furnace, and thus the full effect of the combustion will be realized. In order to effect this, it is necessary to admit more air into the furnace than is theoretically necessary for combustion, and, generally, admission of air above the fire through holes in the furnace-door is found to be beneficial, and a combustion-chamber beyond the furnace is frequently added. In the practical working of boiler-furnaces, only a small portion of the carbon passes off unconsumed. Very complete experimental investigations on the combustion of coal have been made by Messrs. Scheurer-Kestner and Meunier-Dollfus, and the results were published in the "Bulletin de la Société Industrielle de Mulhouse," 1868, 1869. Many of the following statements are taken from their reports. The heating power of fuel is ordinarily measured by the number of thermal units given out by its combustion, or the number of units of evaporation. A thermal unit is the amount of heat required to raise the temperature of a pound of water from 39° to 40° Fahr., and a unit of evaporation is 966.6 thermal units, being the amount of heat required to change a pound of water at 212° into steam of atmospheric pressure. A unit of evaporation is commonly called the equivalent evaporation from and at 212°, and is expressed in pounds. The advantage of having a unit of this kind will be obvious from the following consideration: In experiments with different kinds of fuel and forms of boiler, the pressure under which evaporation takes place, and the temperature of the fuel, likewise vary; and, in order to compare the various experiments, it is necessary to change the results to equivalent results for the same temperature and pressure. There is no *universal* standard of temperature and pressure adopted for purposes of comparison, but the equivalent evaporation from and at 212° is most generally accepted by engineers. The table on page 157 is designed to facilitate the reduction to this standard.

A table of this kind may be constructed by finding (either by calculation or from a steam table) the total amount of heat required to evaporate a pound of water at various pressures, and from various temperatures of feed, the amount for any particular case being:

$$\text{Heat of evaporation above } 32° - \left\{ \begin{array}{l} \text{heat required to raise the temperature of the feed-water from } 32° \\ \quad \text{to the given temperature.} \end{array} \right.$$

And then dividing the quantities so obtained by the latent heat of a pound of steam at the temperature of boiling water, and at atmospheric pressure, as given in the article Expansion of Steam.

To illustrate the use of this table, suppose it is determined, by experiment, that the evaporation of a certain boiler is 8.25 lbs. of water per pound of coal; the absolute pressure of evaporation being 65 lbs. per square inch, and the temperature of the feed 90°, what is the equivalent evaporation from and at 212°? To solve this example, it is only necessary to multiply the actual evaporation, 8.25, by the proper factor, 1.154, obtained from the table, so that the equivalent evaporation per pound of coal is $8.25 \times 1.154 = 9.52$ lbs.

In experiments with different fuels, the amount of ashes frequently varies so much that it is advisable, for purposes of comparison, to use the results obtained after deducting the ashes, or those due to the *combustible*.

*Calorific Effect.*—When coal is burned in the furnace of a boiler, its total heating effect may generally be classified as follows:

1. The useful effect, or the heat utilized in the evaporation of water in the boiler.
2. Heat required to raise the temperature of the products of combustion to the chimney temperature.
3. Heat not given out on account of the presence of combustible gas in the products of combustion.
4. Heat required to vaporize the water in the coal and that formed in combustion.
5. Heat not given out, on account of the presence of carbon in the smoke.
6. Heat in the refuse, when drawn from the furnace, and that lost by the presence of carbon in the refuse.
7. Heat lost by radiation from surfaces other than those of the boiler.

*Table of Factors of Evaporation.*

| TEMPERATURE OF FEED-WATER, FAHRENHEIT. | ABSOLUTE PRESSURE OF STEAM, IN POUNDS PER SQUARE INCH. | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 15. | 20. | 30. | 40. | 50. | 60. | 70. | 80. | 90. | 100. | 110. | 120. | 130. | 140. | 150. | 160. | 170. | 180. | 190. | 200. |
| Degrees. | | | | | | | | | | | | | | | | | | | | |
| 32 | 1.187 | 1.192 | 1.199 | 1.204 | 1.209 | 1.212 | 1.216 | 1.218 | 1.221 | 1.223 | 1.226 | 1.228 | 1.230 | 1.231 | 1.233 | 1.225 | 1.236 | 1.238 | 1.239 | 1.240 |
| 35 | 1.184 | 1.189 | 1.196 | 1.201 | 1.206 | 1.209 | 1.213 | 1.215 | 1.218 | 1.220 | 1.223 | 1.225 | 1.227 | 1.228 | 1.230 | 1.232 | 1.233 | 1.235 | 1.236 | 1.237 |
| 40 | 1.179 | 1.184 | 1.191 | 1.196 | 1.201 | 1.204 | 1.208 | 1.219 | 1.213 | 1.215 | 1.218 | 1.220 | 1.222 | 1.223 | 1.225 | 1.227 | 1.228 | 1.230 | 1.231 | 1.232 |
| 45 | 1.173 | 1.178 | 1.185 | 1.190 | 1.195 | 1.198 | 1.202 | 1.201 | 1.207 | 1.209 | 1.212 | 1.214 | 1.216 | 1.217 | 1.219 | 1.221 | 1.222 | 1.224 | 1.225 | 1.226 |
| 50 | 1.168 | 1.173 | 1.180 | 1.185 | 1.190 | 1.193 | 1.197 | 1.199 | 1.202 | 1.204 | 1.207 | 1.209 | 1.211 | 1.212 | 1.214 | 1.216 | 1.217 | 1.219 | 1.220 | 1.221 |
| 55 | 1.163 | 1.168 | 1.175 | 1.180 | 1.185 | 1.188 | 1.192 | 1.194 | 1.197 | 1.199 | 1.202 | 1.204 | 1.206 | 1.207 | 1.209 | 1.211 | 1.212 | 1.214 | 1.215 | 1.216 |
| 60 | 1.158 | 1.163 | 1.170 | 1.175 | 1.180 | 1.183 | 1.187 | 1.189 | 1.192 | 1.194 | 1.197 | 1.199 | 1.201 | 1.202 | 1.204 | 1.206 | 1.207 | 1.209 | 1.210 | 1.211 |
| 65 | 1.153 | 1.158 | 1.165 | 1.170 | 1.175 | 1.178 | 1.182 | 1.184 | 1.187 | 1.189 | 1.192 | 1.194 | 1.196 | 1.197 | 1.199 | 1.201 | 1.202 | 1.204 | 1.205 | 1.206 |
| 70 | 1.148 | 1.153 | 1.160 | 1.165 | 1.170 | 1.173 | 1.177 | 1.179 | 1.182 | 1.184 | 1.187 | 1.189 | 1.191 | 1.192 | 1.194 | 1.196 | 1.197 | 1.199 | 1.200 | 1.201 |
| 75 | 1.143 | 1.148 | 1.155 | 1.160 | 1.165 | 1.168 | 1.172 | 1.174 | 1.177 | 1.179 | 1.182 | 1.184 | 1.186 | 1.187 | 1.189 | 1.191 | 1.192 | 1.194 | 1.195 | 1.196 |
| 80 | 1.137 | 1.142 | 1.149 | 1.154 | 1.159 | 1.162 | 1.166 | 1.168 | 1.171 | 1.173 | 1.176 | 1.178 | 1.180 | 1.181 | 1.183 | 1.185 | 1.186 | 1.188 | 1.189 | 1.190 |
| 85 | 1.132 | 1.137 | 1.144 | 1.149 | 1.154 | 1.157 | 1.161 | 1.163 | 1.166 | 1.168 | 1.171 | 1.173 | 1.175 | 1.176 | 1.178 | 1.180 | 1.181 | 1.183 | 1.184 | 1.185 |
| 90 | 1.127 | 1.132 | 1.139 | 1.144 | 1.149 | 1.152 | 1.156 | 1.158 | 1.161 | 1.163 | 1.166 | 1.168 | 1.170 | 1.171 | 1.173 | 1.175 | 1.176 | 1.178 | 1.179 | 1.180 |
| 95 | 1.122 | 1.127 | 1.134 | 1.139 | 1.144 | 1.147 | 1.151 | 1.153 | 1.156 | 1.158 | 1.161 | 1.163 | 1.165 | 1.166 | 1.168 | 1.170 | 1.171 | 1.173 | 1.174 | 1.175 |
| 100 | 1.117 | 1.122 | 1.129 | 1.134 | 1.139 | 1.142 | 1.146 | 1.148 | 1.151 | 1.153 | 1.156 | 1.158 | 1.160 | 1.161 | 1.163 | 1.165 | 1.166 | 1.168 | 1.169 | 1.170 |
| 105 | 1.111 | 1.116 | 1.123 | 1.128 | 1.133 | 1.136 | 1.140 | 1.142 | 1.145 | 1.147 | 1.150 | 1.152 | 1.154 | 1.155 | 1.157 | 1.159 | 1.160 | 1.162 | 1.163 | 1.164 |
| 110 | 1.106 | 1.111 | 1.118 | 1.123 | 1.128 | 1.131 | 1.135 | 1.137 | 1.140 | 1.142 | 1.145 | 1.147 | 1.149 | 1.150 | 1.152 | 1.154 | 1.155 | 1.157 | 1.158 | 1.159 |
| 115 | 1.101 | 1.106 | 1.113 | 1.118 | 1.123 | 1.126 | 1.130 | 1.132 | 1.135 | 1.137 | 1.140 | 1.142 | 1.144 | 1.145 | 1.147 | 1.149 | 1.150 | 1.152 | 1.153 | 1.154 |
| 120 | 1.096 | 1.101 | 1.108 | 1.113 | 1.118 | 1.121 | 1.125 | 1.127 | 1.130 | 1.132 | 1.135 | 1.137 | 1.139 | 1.140 | 1.142 | 1.144 | 1.145 | 1.147 | 1.148 | 1.149 |
| 125 | 1.091 | 1.096 | 1.103 | 1.108 | 1.113 | 1.116 | 1.120 | 1.122 | 1.125 | 1.127 | 1.130 | 1.132 | 1.134 | 1.135 | 1.137 | 1.139 | 1.140 | 1.142 | 1.143 | 1.144 |
| 130 | 1.085 | 1.090 | 1.097 | 1.102 | 1.107 | 1.110 | 1.114 | 1.116 | 1.119 | 1.121 | 1.124 | 1.126 | 1.128 | 1.129 | 1.131 | 1.133 | 1.184 | 1.136 | 1.137 | 1.138 |
| 135 | 1.080 | 1.085 | 1.092 | 1.097 | 1.102 | 1.105 | 1.109 | 1.111 | 1.114 | 1.116 | 1.119 | 1.121 | 1.123 | 1.124 | 1.126 | 1.128 | 1.129 | 1.131 | 1.132 | 1.133 |
| 140 | 1.075 | 1.080 | 1.087 | 1.092 | 1.097 | 1.100 | 1.104 | 1.106 | 1.109 | 1.111 | 1.114 | 1.116 | 1.118 | 1.119 | 1.121 | 1.123 | 1.124 | 1.126 | 1.127 | 1.128 |
| 145 | 1.070 | 1.075 | 1.082 | 1.087 | 1.092 | 1.095 | 1.099 | 1.101 | 1.104 | 1.106 | 1.109 | 1.111 | 1.113 | 1.114 | 1.116 | 1.118 | 1.119 | 1.121 | 1.122 | 1.123 |
| 150 | 1.065 | 1.070 | 1.077 | 1.082 | 1.087 | 1.090 | 1.094 | 1.096 | 1.099 | 1.101 | 1.104 | 1.106 | 1.108 | 1.109 | 1.111 | 1.113 | 1.114 | 1.116 | 1.117 | 1.118 |
| 155 | 1.059 | 1.064 | 1.071 | 1.076 | 1.081 | 1.084 | 1.088 | 1.090 | 1.099 | 1.095 | 1.098 | 1.100 | 1.102 | 1.103 | 1.105 | 1.107 | 1.108 | 1.110 | 1.111 | 1.112 |
| 160 | 1.054 | 1.059 | 1.066 | 1.071 | 1.076 | 1.079 | 1.083 | 1.085 | 1.088 | 1.090 | 1.093 | 1.095 | 1.097 | 1.098 | 1.100 | 1.102 | 1.103 | 1.105 | 1.106 | 1.107 |
| 165 | 1.049 | 1.054 | 1.061 | 1.066 | 1.071 | 1.074 | 1.078 | 1.080 | 1.083 | 1.085 | 1.088 | 1.090 | 1.092 | 1.093 | 1.095 | 1.097 | 1.098 | 1.100 | 1.101 | 1.102 |
| 170 | 1.044 | 1.049 | 1.056 | 1.061 | 1.066 | 1.069 | 1.073 | 1.075 | 1.078 | 1.080 | 1.083 | 1.085 | 1.087 | 1.088 | 1.090 | 1.092 | 1.093 | 1.095 | 1.096 | 1.097 |
| 175 | 1.039 | 1.044 | 1.051 | 1.056 | 1.061 | 1.064 | 1.068 | 1.070 | 1.073 | 1.075 | 1.078 | 1.080 | 1.082 | 1.083 | 1.085 | 1.087 | 1.088 | 1.090 | 1.091 | 1.092 |
| 180 | 1.033 | 1.038 | 1.045 | 1.050 | 1.055 | 1.058 | 1.062 | 1.064 | 1.067 | 1.069 | 1.072 | 1.074 | 1.076 | 1.077 | 1.079 | 1.081 | 1.082 | 1.084 | 1.085 | 1.086 |
| 185 | 1.028 | 1.033 | 1.040 | 1.045 | 1.050 | 1.053 | 1.057 | 1.059 | 1.062 | 1.064 | 1.067 | 1.069 | 1.071 | 1.073 | 1.074 | 1.076 | 1.077 | 1.079 | 1.080 | 1.081 |
| 190 | 1 023 | 1.028 | 1.035 | 1.040 | 1.045 | 1.048 | 1.052 | 1.054 | 1.057 | 1.059 | 1.062 | 1.064 | 1.066 | 1.067 | 1.069 | 1.071 | 1.072 | 1.074 | 1.075 | 1.076 |
| 195 | 1.018 | 1.023 | 1.030 | 1.035 | 1.040 | 1.043 | 1.047 | 1.049 | 1.052 | 1.054 | 1.057 | 1.059 | 1.061 | 1.062 | 1.064 | 1.066 | 1.066 | 1.069 | 1.070 | 1.071 |
| 200 | 1.013 | 1.018 | 1.025 | 1.030 | 1.035 | 1.038 | 1.042 | 1.044 | 1.047 | 1.049 | 1.052 | 1.054 | 1.056 | 1.057 | 1.059 | 1.061 | 1.062 | 1.064 | 1.065 | 1.066 |
| 205 | 1.007 | 1.012 | 1.019 | 1.024 | 1.029 | 1.032 | 1.036 | 1.038 | 1.041 | 1.043 | 1.046 | 1.048 | 1.050 | 1.051 | 1.053 | 1.055 | 1.056 | 1.058 | 1.059 | 1.060 |
| 210 | 1.002 | 1.007 | 1.014 | 1.019 | 1.024 | 1.027 | 1.031 | 1.033 | 1.036 | 1.038 | 1.041 | 1.043 | 1.045 | 1.046 | 1.048 | 1.050 | 1.051 | 1.053 | 1.054 | 1.055 |
| 212 | 1.000 | 1.005 | 1.012 | 1.017 | 1.022 | 1.025 | 1.029 | 1.031 | 1.034 | 1.036 | 1.039 | 1.041 | 1.043 | 1.044 | 1.046 | 1.048 | 1.049 | 1.051 | 1.052 | 1.053 |

The experiments of Messrs. Kestner and Meunier with different varieties of fuel, in an elephant-boiler with heaters, give the following average values of the distribution of heat:

*Summary of Messrs. Kestner and Meunier's Experiments on Distribution of Heat in an Elephant-Boiler.*

| HOW EXPENDED. | PER CENT. OF THE HEAT EXPENDED. | |
|---|---|---|
| | Per Pound of Combustible. | Per Pound of Coal. |
| Useful effect | 61.6 | 60.5 |
| Products of combustion | 5.5 | 5.5 |
| Combustible gas | 5.3 | 5. |
| Steam in smoke | 2.8 | 2.5 |
| Carbon in smoke | .5 | .5 |
| Refuse | .... | 1.5 |
| Radiation from masonry | 24.3 | 24.5 |
| | 100.0 | 100.0 |

These experiments were made with care and were of sufficient duration to secure average conditions, so that the results are entitled to great confidence.

It will be observed that the per cent. of useful effect is much smaller than is given by most experimenters, and this is due to the use of a higher number to express the calorific effect of the fuel. The ordinary method of determining the calorific effect is by a calculation from the elementary analysis of the coal, using the following formula:

$C =$ proportion of carbon. $H =$ proportion of hydrogen. $O =$ proportion of oxygen.

$$\text{Calorific effect per pound of coal in thermal units} = 14{,}500 \times \left\{ C + 4.28 \left( H - \frac{O}{8} \right) \right\}.$$

Thus, the calorific effect of a coal containing 76 per cent. $C$, 4 per cent. $H$, and 4 per cent. $O$, would be, by calculation, $14{,}500 \times (0.76 + 4.28 \times 0.035) = 13{,}192$.

The experiments of Messrs. Kestner and Meunier, made with the same instrument that was used for determining the calorific effect of carbon and hydrogen, show conclusively that this formula is very unreliable, and that the calorific effect of a given coal is almost invariably higher than the number obtained by the calculation from its analysis. Their conclusion seems to be indisputable, and is accepted by the best authorities, although no very satisfactory explanation of the fact has yet been given. It seems probable that the heating effect depends upon the state in which the carbon exists in the coal; and that while the effect of the combustion of carbon in the form of charcoal has been accurately determined, it may be much higher in the case of carbon that is not so much condensed. Dr. Percy, one of the few English writers who have referred to these results, thinks that more extended experiments are necessary, before the matter can be satisfactorily explained. The reader will find a very interesting discussion of these experiments, by M. L. Gruner, in the *Engineering and Mining Journal*, xviii.

The accompanying tables contain a good summary of the experiments referred to:

*Summary of Analyses and Calorimetric Trials of Fuel, by Messrs. Scheurer-Kestner and Meunier-Dollfus.*

| ARGUMENT. | | RONCHAMP. | | | | SAARBRÜCK. | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | No. 1. | No. 2. | No. 3. | No. 4. | Duttweiler. | Altenwald. | Heinitz. | Friedrichsthal. | Louisenthal. |
| Elementary analysis of coal. | Carbon | 76.45 | 68.65 | 76.23 | 73.1 | 71.25 | 69.3 | 70.33 | 67.81 | 64.69 |
| | Hydrogen | 4.39 | 3.97 | 4.06 | 3.75 | 4.1 | 4.26 | 4.3 | 4.19 | 3.94 |
| | Solid refuse | 15.02 | 20.8 | 12.8 | 16.19 | 13.25 | 13.5 | 11.57 | 12.7 | 12.38 |
| | Nitrogen | 1.09 | 1.06 | 1. | 1. | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 |
| | Oxygen | 3.05 | 4.75 | 5.91 | 4.87 | 9.15 | 9.9 | 11.51 | 13.8 | 15.02 |
| | Water | ...... | 0.77 | ...... | 1.09 | 1.75 | 2.54 | 1.79 | 1. | 3.57 |
| Combustible and volatile constituents. | Uncombined carbon | 72.57 | 74.74 | 71.44 | 71.58 | 62.84 | 63.15 | 61.57 | 58.44 | 56.15 |
| | Carbon in hydrocarbons | 17.39 | 12.75 | 15.99 | 16.8 | 20.98 | 19.59 | 18.92 | 20.53 | 20.72 |
| | Hydrogen | 5.09 | 5.1 | 4.56 | 4.42 | 4.6 | 4.73 | 4.71 | 4.67 | 4.68 |
| | Nitrogen | 1.28 | 1.35 | 1.14 | 1.2 | 0.71 | 0.66 | 0.68 | 0.59 | 0.6 |
| | Oxygen | 3.67 | 6.06 | 6.87 | 6. | 10.87 | 11.85 | 14.12 | 15.77 | 17.85 |
| Heat of combustion per pound of combustible, by experiment. | Thermal units | 16,493 | 16,401 | 16,346 | 16,103 | 15,703 | 15,539 | 15,277 | 15,223 | 14,787 |
| | Pounds of water, from and at 212° | 17.06 | 16.98 | 16.91 | 16.66 | 16.25 | 16.08 | 15.8 | 15.75 | 15.8 |
| Excess of experimental value above that calculated from analysis: thermal units | | 547 | 1,186 | 1,244 | 1,013 | 1,319 | 1,195 | 1,361 | 1,548 | 1,379 |
| Difference between experimental and calculated values, in per cent. of experimental value | | 3.32 | 7.08 | 7.61 | 6.29 | 8.4 | 7.69 | 8.91 | 10.17 | 9.32 |

The following table contains analyses and experimental heat of combustion of other coals, by the same experimenters, the data being taken from the "Bulletin de la Société Industrielle de Mulhouse" for 1868, 1869, and 1871; "Annales de Chimie," Fourth Series, xxx.; Fifth Series, ii., xxi.; and Sixth Series, ii.; and "Comptes Rendus de l'Académie," 1869, Second Series:

*Summary of Experiments by Messrs. Kestner and Meunier on Heat of Combustion of Various Coals.*

| NAME. | COMBUSTIBLE AND VOLATILE CONSTITUENTS. | | | HEAT OF COMBUSTION PER POUND OF COMBUSTIBLE, BY EXPERIMENT. | |
|---|---|---|---|---|---|
| | Carbon. | Hydrogen. | Nitrogen and Oxygen. | Thermal Units. | Pounds of Water evaporated, from and at 212°. |
| Saarbrück, Sulzbach | 83.05 | 4.95 | 12. | 15,485 | 16.02 |
| " Von der Heydt | 81.56 | 4.98 | 13.46 | 15,232 | 15.76 |
| Creusot, caking (Chaptal Shaft) | 88.48 | 4.41 | 7.11 | 17,320 | 17.92 |
| " anthracite (St. Pierre Shaft) | 92.36 | 3.66 | 3.98 | 17,021 | 17.61 |
| " semi-bituminous (St. Paul) | 90.07 | 4.1 | 5.13 | 16,965 | 17.55 |
| " flaming (St. Paul) | 90.79 | 4.24 | 4.97 | 16,673 | 17.25 |
| Blanzy, Mouteeau | 78.58 | 5.23 | 16.19 | 14,985 | 15.5 |
| " anthracite | 87.02 | 4.72 | 8.26 | 16,400 | 16.97 |
| Anzin | 84.45 | 4.21 | 11.32 | 16,663 | 17.24 |
| Denain | 83.94 | 4.43 | 11.63 | 16,290 | 16.85 |
| English, Bwlf | 91.08 | 3.83 | 5.09 | 15,804 | 16.35 |
| " Powell Duffryn | 92.49 | 4.04 | 3.47 | 16,108 | 16.66 |
| Russian, Grouchefski anthracite | 96.66 | 1.35 | 1.99 | 14,866 | 15.38 |
| " Miouski caking | 91.45 | 4.5 | 4.05 | 15,651 | 16.19 |
| " Goloubofski flaming | 82.67 | 5.07 | 12.26 | 14,438 | 14.94 |
| Lignite, blue from Rocher | 72.98 | 4.04 | 22.98 | 11,669 | 12.07 |
| " flaming from Manosque | 70.57 | 5.44 | 23.99 | 13,253 | 13.71 |
| " lean " " | 66.31 | 4.85 | 28.84 | 12,584 | 13.02 |
| " caking from Bohemia | 76.58 | 8.27 | 15.15 | 14,263 | 14.76 |
| " changing to fossil-wood | 66.51 | 4.72 | 28.77 | 11,444 | 11.84 |
| Fossil-wood changing to lignite | 67.60 | 4.55 | 27.85 | 11,360 | 11.75 |
| Russian lignite, from Toula | 73.72 | 6.09 | 20.19 | 13,837 | 14.31 |

It will be observed that some of the coals upon which experiments were made have a similar composition to those of the United States, whence it is reasonable to conclude that the calorific effect of the latter has been greatly underestimated. Experimental investigation of this subject is very desirable. The most complete information on American coals is to be found in Prof. Walter F. Johnson's "Report to the Navy Department on American Coals." Prof. Johnson's experiments included elementary analyses and descriptions of the coals, with practical trials by burning them in the furnace of a boiler, and making analyses of the products of combustion. These latter analyses have usually been considered as authority in the determination of the amount of air required for combustion, which is assumed, in general, to be twice as much as is theoretically necessary. The number of pounds required for chemical combustion is

$$12\,C + 36\left(H - \frac{O}{8}\right),$$

in which formula, as before,

$C =$ per cent. of carbon.
$H =$ " " hydrogen
$O =$ " " oxygen.

Thus, for the coal whose composition is given in the last example, the number of pounds of air theoretically necessary per pound of coal would be $12 \times 0.76 + 36 \times 0.035 = 10.38$. In Prof. Johnson's analyses of the products of combustion he did not collect samples that represented means for considerable periods, and the individual experiments in the case of a particular coal were so few that it is doubtful whether the accurate mean results were obtained.

All the coals analyzed by Messrs. Kestner and Meunier were afterward tried in the furnace of a boiler, and the products of combustion were drawn off in such a manner as to secure samples that represented the averages of a day's run. The results obtained in this manner showed that a less amount of air in excess was necessary than is commonly supposed, and special experiments with various amounts of air indicated that, under the conditions of those experiments, an excess of air of 33 per cent. above that theoretically necessary gave the best results. Whether this is true in general can only be settled by further experiments.

Summaries of the results obtained by Prof. Johnson and Messrs. Kestner and Meunier are given in the tables on pages 160 and 161. In comparing the results of such experiments, it is to be remembered, as pointed out by Dr. Percy, that they do not certainly determine the relative economic effect of the different coals, since they are made under approximately the same condition as to boiler, furnace etc., which conditions may be much more favorable to some kinds of fuel than to others.

Land Boilers.—The boilers illustrated in Figs. 354 to 396 inclusive, selected from the great variety of examples that have been and are still in use, will give a fair idea of past and present practice.

Boilers may be classed generally as flue and tubular, with some special exceptions, in the case of sectional boilers. Both flue and tubular boilers may have external or internal furnaces, and tubular boilers may be still further divided into fire-tube and water-tube boilers, the former, as the name implies, having the water around the tubes, and the latter having it within them. Marine boilers commonly have internal furnaces, while those used for stationary purposes may be either internally or externally fired.

*Summary of Prof. Johnson's Experiments on Coals.*

| NUMBER FOR REFERENCE. | DESIGNATION OF COAL. | WEIGHT IN POUNDS PER CUBIC FOOT. | | ANALYSIS, PARTS IN 100. | | | | | Per Cent. of Refuse obtained on Trial. | Pounds of Water evaporated from and at 212° in Experimental Boiler. | PRODUCTS OF COMBUSTION, PARTS IN 100. | | Pounds of Air supplied per Pound of Coal. | NUMBER FOR REFERENCE. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Of Solid Coal. | Of Broken Coal. | Moisture. | Sulphur. | Volatile Combustible. | Fixed Carbon. | Solid Refuse. | | | Carbonic Acid. | Oxygen. | | |
| | CLASS I.—ANTHRACITE—NATURAL COKE—ARTIFICIAL COKE—MIXTURES. | | | | | | | | | | | | | |
| 1 | Beaver Meadow, Slope No. 3 ........ Pennsylvania. | 100.65 | 54.93 | 1.5 | .01 | 2.38 | 88.94 | 7.11 | 9.7 | 10.11 | 10.19 | 10.99 | 20.4 | 1 |
| 2 | " " " No. 5 ........ " | 96.93 | 56.19 | .89 | .06 | 2.66 | 91.47 | 5.15 | 6.8 | 10.84 | 7.84 | 16.31 | 28.5 | 2 |
| 3 | Forest Improvement ........ " | 92.31 | 53.66 | 1.79 | .02 | 3.07 | 90.75 | 4.41 | 7. | 11.02 | 9.77 | 10.89 | 21.7 | 3 |
| 4 | Peach Mountain ........ " | 91.51 | 53.79 | 1.9 | .01 | 2.96 | 89.02 | 6.13 | 7. | 11.05 | 10.89 | 11.1 | 18.4 | 4 |
| 5 | Lehigh ........ " | 99.39 | 55.32 | .... | .... | 5.28 | 89.15 | 5.56 | 7.6 | 9.75 | 4.57 | 16.7 | 47.9 | 5 |
| 6 | Lackawanna ........ " | 88.84 | 48.89 | 2.12 | .12 | 3.91 | 87.74 | 6.35 | 9.1 | 10.93 | 10.6 | 10.84 | 19.4 | 6 |
| 7 | Lykens Valley ........ " | 86.82 | 48.56 | .11 | .09 | 6.88 | 83.84 | 9.25 | 12.2 | 10.97 | ..... | ..... | .... | 7 |
| 8 | Beaver Meadow (in navy yard) ........ " | ..... | 55.08 | .... | .... | ..... | ..... | 8.1 | 8.1 | 10.13 | ..... | ..... | .... | 8 |
| 9 | Natural coke of Virginia ........ Virginia. | 82.7 | 44.64 | 1.12 | .47 | 12.44 | 75.08 | 11.83 | 18.7 | 10.63 | 9.22 | 12.12 | 19.7 | 9 |
| 10 | Coke of Midlothian coal ........ " | ..... | 32.7 | 2.81 | .... | ..... | ..... | 16.55 | 16.6 | 10.52 | 13.36 | 7.94 | 14.5 | 10 |
| 11 | " Neff's (Cumberland) coal ........ Maryland. | ..... | 31.57 | .... | .... | ..... | ..... | 13.34 | 13.5 | 10.54 | ..... | ..... | .... | 11 |
| 12 | Mixture of ⅓ Cumberland, ⅔ Beaver Meadow ........ " | ..... | 54.29 | .... | .... | ..... | ..... | 8.88 | 9. | 9.84 | ..... | ..... | .... | 12 |
| 13 | " " " " " " ........ " | ..... | 54.51 | .... | .... | ..... | ..... | 8.18 | 8.2 | 10.13 | ..... | ..... | .... | 13 |
| | CLASS II.—FREE-BURNING BITUMINOUS COALS OF MARYLAND AND PENNSYLVANIA. | | | | | | | | | | | | | |
| 14 | New York & Maryland Mining Company ........ Maryland. | 89.44 | 53.7 | 1.79 | .... | 12.31 | 73.5 | 12.4 | 13.2 | 11.45 | 11.39 | 9.59 | 15.7 | 14 |
| 15 | Neff's Cumberland ........ " | 83.28 | 54.29 | 2.46 | .... | 12.67 | 74.53 | 10.34 | 11.1 | 10.81 | 9.98 | 10.78 | 20.1 | 15 |
| 16 | Easby's "Coal-in-Store" ........ " | 81.69 | 53.47 | .67 | .... | 14.98 | 76.26 | 8.08 | 8.8 | 11.17 | 8.59 | 10.8 | 23.6 | 16 |
| 17 | Atkinson & Templeman's ........ " | 82.09 | 52.92 | .45 | .... | 15.53 | 76.69 | 7.33 | 8.2 | 11.87 | 10.43 | 11.26 | 18.3 | 17 |
| 18 | Easby & Smith's ........ " | 83.26 | 51.16 | .89 | .... | 15.52 | 74.29 | 9.3 | 10.1 | 11.29 | 16.02 | 8.4 | 13.1 | 18 |
| 19 | Dauphin and Susquehanna ........ Pennsylvania. | 90.19 | 50.54 | .45 | .27 | 13.82 | 74.24 | 11.29 | 16.5 | 11.4 | 10.24 | 9.7 | 18.3 | 19 |
| 20 | Blossburg ........ " | 82.73 | 53.05 | 1.34 | .85 | 14.78 | 73.11 | 10.77 | 11.5 | 11.17 | 9.77 | 11. | 20.2 | 20 |
| 21 | Lycoming Creek ........ " | 86.74 | 55.38 | .67 | .03 | 13.84 | 71.53 | 13.96 | 13.1 | 7.84 | 9.65 | 11.29 | 20.1 | 21 |
| 22 | Quin's Run ........ " | 83.22 | 50.34 | .84 | .1 | 17.97 | 72.79 | 8.41 | 9.3 | 11.82 | 10.34 | 10.21 | 20.6 | 22 |
| 23 | Karthaus ........ " | 80.22 | 52.54 | 1.28 | 1.58 | 19.53 | 73.77 | 7. | 8. | 9.93 | ..... | ..... | .... | 23 |
| 24 | Cambria County ........ " | 87.94 | 53.46 | 2.46 | 1.5 | 20.52 | 69.37 | 9.15 | 9.5 | 10.39 | ..... | ..... | .... | 24 |
| | CLASS III.—BITUMINOUS COKING COALS FROM THE EASTERN COAL FIELD OF VIRGINIA IN THE NEIGHBORHOOD OF RICHMOND. | | | | | | | | | | | | | |
| 25 | Barr's Deep Run ........ Virginia. | 86.41 | 53.17 | 1.79 | .... | 19.78 | 67.96 | 10.47 | 11.5 | 10.31 | 7.89 | 13.21 | 26. | 25 |
| 26 | Crouch & Snead's ........ " | 90.71 | 53.59 | 1.79 | .43 | 24.38 | 59.98 | 14.28 | 15.2 | 10. | ..... | ..... | .... | 26 |
| 27 | Midlothian (900-feet shaft) ........ " | 87.5 | 50.52 | 1.17 | .... | 27.28 | 61.08 | 10.47 | 11.1 | 9.71 | 11.21 | 9.94 | 17.9 | 27 |
| 28 | Creek Company's coal ........ " | 82.48 | 46.5 | 1.45 | 2.89 | 32.47 | 60.3 | 8.57 | 9.2 | 9.38 | 10.05 | 12.11 | 28.9 | 28 |
| 29 | Clover Hill ........ " | 80.36 | 45.49 | 1.34 | .51 | 32.21 | 56.83 | 10.13 | 11.6 | 8.8 | ..... | ..... | .... | 29 |
| 30 | Chesterfield Mining Company ........ " | 80.57 | 45.55 | 1.9 | 1.96 | 32.63 | 58.79 | 8.63 | 9.7 | 10.12 | 6.72 | 13.19 | 29.5 | 30 |
| 31 | Midlothian (average) ........ " | 80.9 | 54.04 | 2.46 | .06 | 29.86 | 53.01 | 14.74 | 15.5 | 9.98 | ..... | ..... | .... | 31 |
| 32 | Tippecanoe ........ " | 84.14 | 45.1 | 1.84 | .38 | 34.54 | 51.62 | 9.37 | 9.1 | 8.57 | 11.14 | 7.78 | 17.8 | 32 |
| 33 | Midlothian (new shaft) ........ " | 82.82 | 47.9 | .67 | 2.29 | 35.77 | 56.4 | 9.44 | 10.7 | 9.95 | 9.6 | 10.73 | 22.6 | 33 |
| 34 | " (screened) ........ " | 80.21 | 45.72 | 1.79 | .2 | 34.7 | 54.06 | 9.66 | 11.1 | 10.18 | 10.46 | 8.95 | 19.9 | 34 |
| | CLASS IV.—FOREIGN BITUMINOUS COALS AND THOSE OF SIMILAR CONSTITUTION WEST OF THE ALLEGHANY MOUNTAINS—PINE WOOD. | | | | | | | | | | | | | |
| 35 | Pictou (from New York) ........ Nova Scotia. | 82.35 | 53.55 | 2.57 | .77 | 27.83 | 56.98 | 13.39 | 13.1 | 9.94 | 10.74 | 9.08 | 17.8 | 35 |
| 36 | Sidney ........ " | 83.66 | 47.44 | 3.13 | .... | 23.81 | 67.57 | 5.49 | 6.4 | 8.66 | 10.36 | 9.54 | 19.5 | 36 |
| 37 | Pictou (Cunard's) ........ " | 82.83 | 49.25 | .78 | .... | 25.97 | 60.74 | 12.51 | 12.5 | 9.86 | ..... | ..... | .... | 37 |
| 38 | Liverpool ........ England. | 78.89 | 47.88 | .89 | .38 | 39.96 | 54.9 | 4.62 | 5.3 | 8.48 | 11.2 | 9.24 | 19.2 | 38 |
| 39 | Newcastle ........ " | 78.54 | 50.82 | 2.01 | .23 | 35.83 | 57. | 5.4 | 6.3 | 9.39 | ..... | ..... | .... | 39 |
| 40 | Scotch ........ Scotland. | 74.95 | 51.09 | 3.01 | .36 | 39.19 | 48.81 | 9.34 | 10.8 | 7.87 | 11.22 | 11.58 | 18. | 40 |
| 41 | Pittsburgh ........ Pennsylvania. | 78.37 | 46.81 | 1.4 | .16 | 36.76 | 54.93 | 7.07 | 9.5 | 8.71 | ..... | ..... | .... | 41 |
| 42 | Cannelton ........ " | 79.54 | 47.65 | 2.6 | .... | 33.99 | 58.44 | 4.97 | 5.6 | 7.88 | 13.21 | 5.51 | 15.9 | 42 |
| 43 | Dry pine wood ........ | ..... | 21.01 | 3.67 | .... | ..... | ..... | .31 | .4 | 4.78 | 9.21 | 10.21 | 21.6 | 43 |

*Summary of Experiments on Fuel, by Messrs. Scheurer-Kestner and Meunier-Dollfus.*

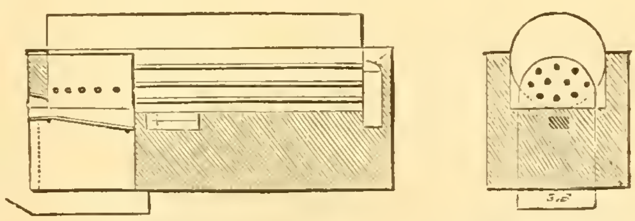
| Number for Reference. | Designation of Fuel. | Per Cent. of Solid Refuse by Analysis. | Per Cent. of Ashes obtained on Trial. | Analysis of Ashes, Parts in 100. | | | Heat of Combustion, in Thermal Units, per Pound of Combustible, by Experiment. | Useful Effect, per Pound of Combustible, on Trial. | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | Water. | Carbon. | Solid Incombustible. | | Thermal Units. | Pounds of Water evaporated from and at 212°. |
| 1 | Ronchamp, I | 12.74 | 17.5 | 3.58 | 14.54 | 81.88 | 16,346 | 10,057 | 10.4 |
| 2 | " II | 16.19 | 13.4 | .5 | 12.9 | 86.6 | 16,411 | 10,438 | 10.8 |
| 3 | Friedrichsthal | 12.7 | 18.4 | 4.05 | 14.15 | 81.8 | 15,223 | 8,928 | 9.24 |
| 4 | Duttweiler | 13.25 | 17.7 | 2.22 | 11.46 | 86.32 | 15,703 | 9,484 | 9.81 |
| 5 | Luisenthal | 12.28 | 16.9 | 1.25 | 12.48 | 86.27 | 14,787 | 8,848 | 8.64 |
| 6 | Altenwald | 13.5 | 16.1 | 2.5 | 16.7 | 80.8 | 15,539 | 9,421 | 9.75 |
| 7 | Heinitz | 11.57 | 12. | .3 | 12.2 | 87.5 | 15,277 | 8,941 | 9.25 |
| 8 | Sulzbach | 10.46 | 14.9 | .25 | 6.72 | 93.03 | 15,212 | 8,847 | 9.15 |
| 9 | Von der Heydt | 10.46 | 16.3 | 7.33 | 11.61 | 81.06 | 15,232 | 8,789 | 9.09 |
| 10 | Blanzy, Montceau | 10.28 | 16.7 | 12.03 | 8.82 | 79.15 | 14,985 | 8,446 | 8.74 |
| 11 | " anthracite | 20.95 | 22.9 | 9.9 | 10.79 | 79.31 | 16,380 | 9,920 | 10.26 |
| 12 | Creusot | 3.63 | 10.7 | 1.15 | 39.4 | 59.45 | 16,942 | 10,472 | 10.83 |
| 13 | Two-thirds Creusot, one-third Ronchamp, I | 7.95 | 14.9 | 4. | 25.3 | 70.7 | 16,758 | 11,268 | 11.66 |
| 14 | Two-thirds Creusot, one-third Ronchamp, II | 11.85 | 17.4 | 13.5 | 18.5 | 68. | 16,758 | 11,131 | 11.52 |
| 15 | Wood charcoal | ..... | .5 | ..... | ..... | ..... | 14,544 | 8,698 | 9. |

| Number for Reference. | Products of Combustion, Parts in 100. | | | Pounds of Air supplied per Pound of Coal. | Distribution of Heat, on Trial, per Pound of Combustible, Parts in 100. | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Excess of Air. | Carbonic Acid. | Nitrogen and Combustible Gas. | | Useful Effect. | Heating Products of Combustion. | Heat in Combustible Gas in Products of Combustion. | Heat in Carbon in Black Smoke. | Heat in Steam in Smoke. | Heat lost by Radiation from Brick-Work, etc. |
| 1 | 24.7 | 13.8 | 61.5 | 12.6 | 61.52 | 4.35 | 7.48 | .77 | 3.02 | 22.86 |
| 2 | 29.1 | 12.9 | 58. | 12.8 | 63.61 | 5.16 | 4.91 | .38 | 2.91 | 23.03 |
| 3 | 32.3 | 12.2 | 55.5 | 12.6 | 58.65 | 4.4 | 7.04 | .75 | 3.33 | 25.83 |
| 4 | 32.8 | 12.1 | 55.1 | 13.4 | 60.4 | 5.08 | 5.02 | .38 | 3.3 | 25.82 |
| 5 | 29.5 | 12.8 | 57.7 | 11.5 | 56.46 | 3.83 | 9.76 | .74 | 3.59 | 25.62 |
| 6 | 32.2 | 12. | 54.8 | 12.8 | 60.63 | 5.57 | 3.16 | .39 | 3.51 | 26.74 |
| 7 | 27.1 | 13.3 | 59.6 | 11.8 | 58.53 | 5.22 | 7.12 | .58 | 3.16 | 25.39 |
| 8 | 32.4 | 12.1 | 55.5 | 13.5 | 58.16 | 5.75 | 5.32 | .39 | 3.58 | 26.8 |
| 9 | 30. | 12.7 | 57.3 | 12.6 | 57.71 | 5.4 | 7.37 | .58 | 3.79 | 25.15 |
| 10 | 23.9 | 14. | 62.1 | 10.6 | 56.36 | 5.72 | 6.01 | .75 | 3.9 | 27.26 |
| 11 | 30.5 | 12.6 | 57.9 | 12.5 | 60.56 | 7.71 | 4.91 | .39 | 3.16 | 23.27 |
| 12 | 47.6 | 8.9 | 43.5 | 20.5 | 61.82 | 7.34 | 2.46 | .37 | 2.38 | 25.63 |
| 13 | 36.2 | 11.4 | 52.4 | 17.1 | 67.24 | 6.04 | 2.41 | .38 | 2.5 | 21.43 |
| 14 | 34.2 | 11.8 | 54. | 16.1 | 66.42 | 6.65 | 2.45 | .39 | 2.64 | 21.45 |
| 15 | 42.5 | 10.1 | 47.4 | 23.4 | 59.8 | 10.55 | 2.08 | ... | .... | 27.57 |

*Flue Boilers.*—Flue boilers are of various forms; the simplest are cylindrical boilers with single or double return flues passing through them. In some the fire is made beneath the boiler at one end, the flame passing beneath the boiler and returning through flues in the boiler to the front end, where the chimney is placed; or, making one return through one flue or set of flues, it is again returned by another set to the rear to the chimney. In another the boiler is made cylindrical, with the lower half cut away at one end for the reception of the grate, and the flame passes directly through the flues, and returns by one side of the boiler and back by the other, or makes but one return, and that beneath the boiler, the chimney being placed at the front end.

Fig. 354. These flues may be either large and few, or more numerous and smaller; the latter class, when tubes are used, are called locomotive boilers, although used for stationary purposes. The advantage of this form is, that the hottest part of the flame is brought in contact with the top of the water; desirable whenever the top of the fireplace and flues can be kept covered with water with certainty. The top of the fire-box being a flat or concave surface, it is therefore weak unless very strongly stayed.

354.



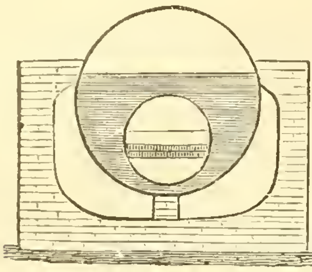
SCALE.—1-20th inch = 1 foot. Longitudinal Section. SCALE.—1-20th inch = 1 foot. Transverse Section.

The Cornish boiler, similar to Fig. 354, is a cylindrical boiler, with an internal flue or flues passing through the boiler, and thence being returned on one side and back on the other; or, making the first return at the sides, is brought back beneath the bottom of the boiler. The diameter of the Cornish boilers is usually about one-sixth of their length; a common proportion is from 36 to 40 feet in length, and from 6 to 7 feet in diameter. The pressure per square inch is from 15 to 35 lbs. The

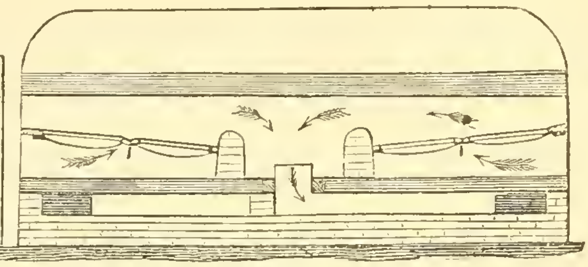
great economy of the Cornish boiler is found in the large proportion of fire, in the slow combustion, in the great care taken in firing and keeping a register of the duty, and in the protection of the boiler from radiation.

Figs. 355 and 356 represent a form of boiler prepared and patented by William B. Johnson. The

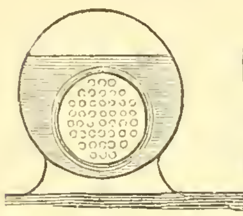
355.



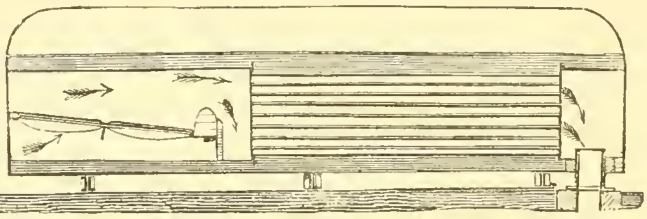
356.



357.

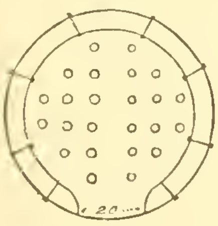


358.

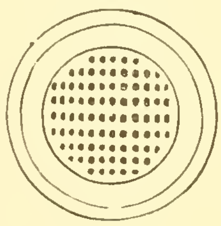


furnaces, two in number, are placed one at each end of the flue, and the gaseous currents therefrom traverse, as shown by the arrows—meeting and mingling with each other in the central space between the two bridges. There the gases are well mixed and ignited, prior to the combined current passing off through the outside bottom flues. Figs. 357 and 358 exhibit similar sections of a tubu-

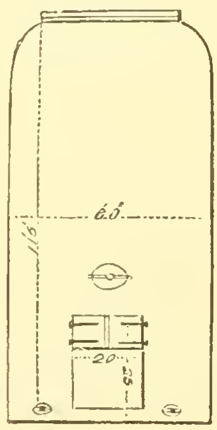
359.



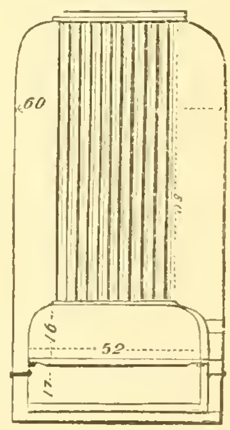
360.



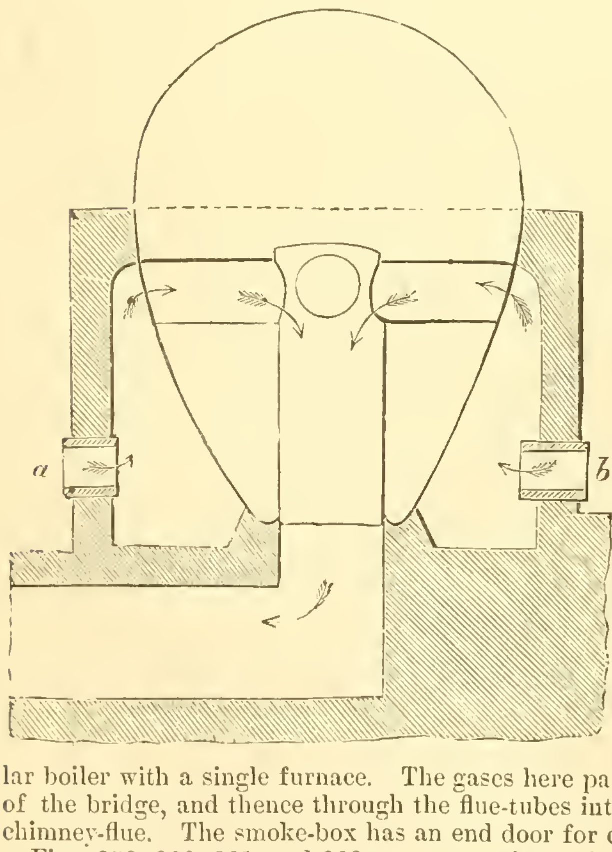
361.



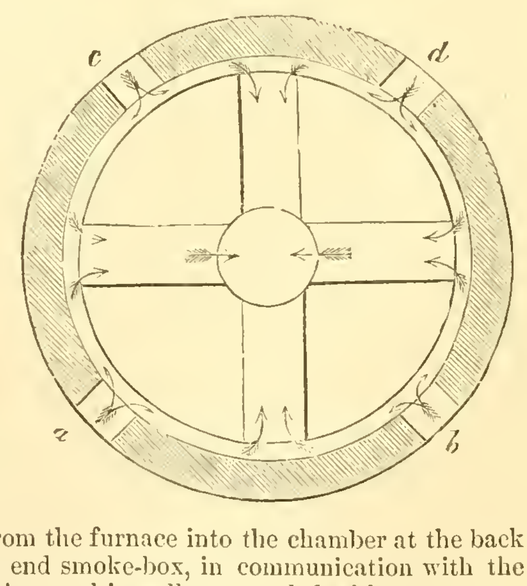
362.




363.

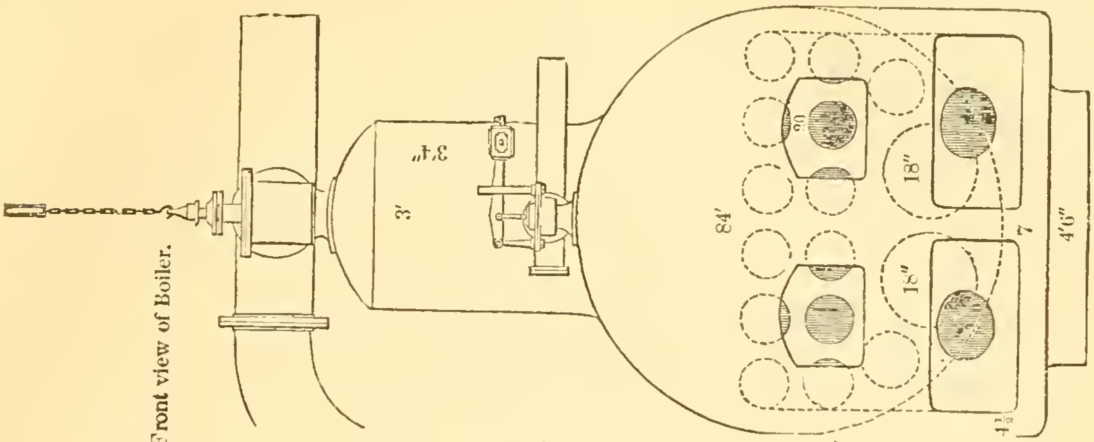



364.

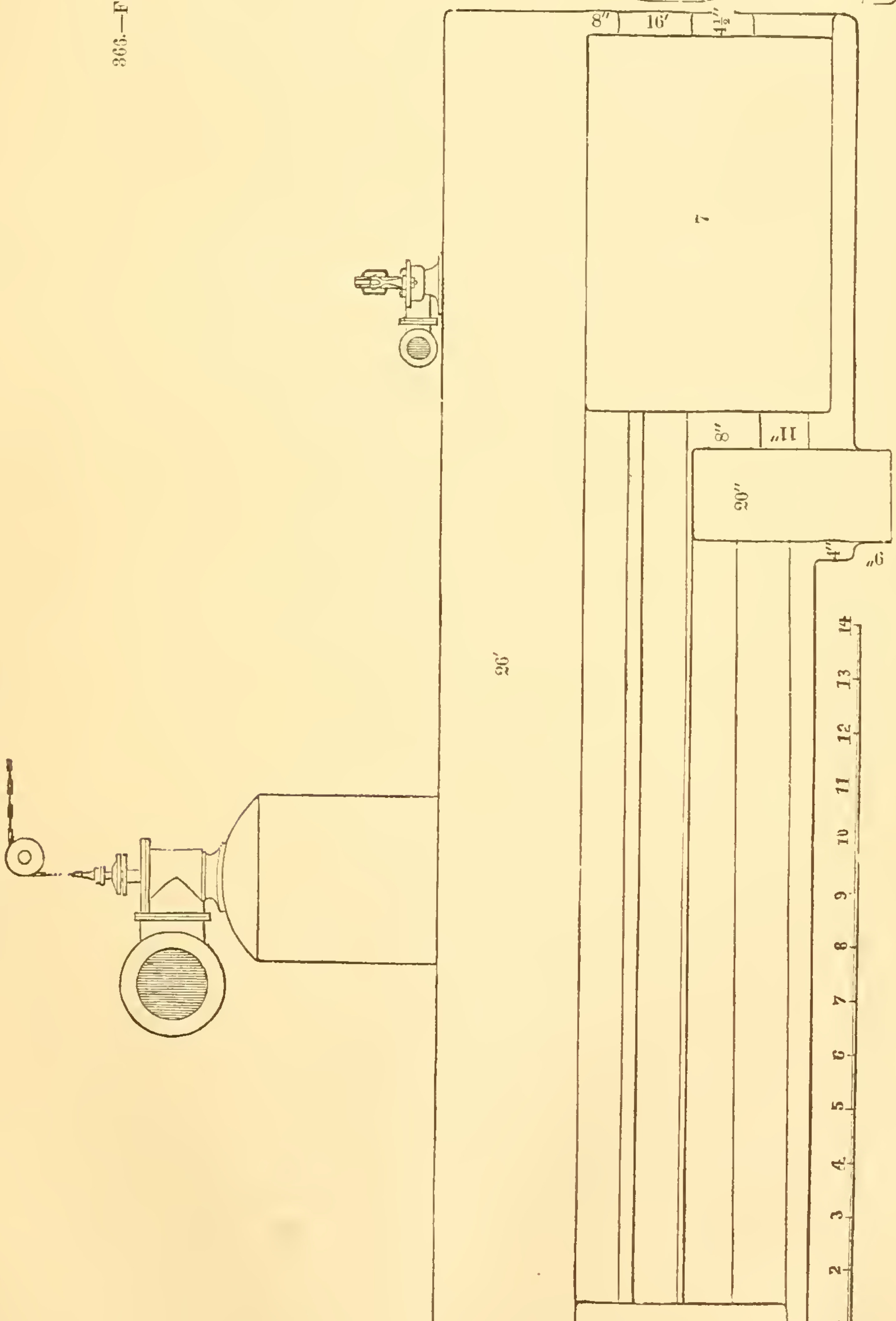



lar boiler with a single furnace. The gases here pass from the furnace into the chamber at the back of the bridge, and thence through the flue-tubes into an end smoke-box, in communication with the chimney-flue. The smoke-box has an end door for cleaning, and is well surrounded with water.

Figs. 359, 360, 361, and 362, represent views of an upright tubular boiler, well adapted in some situations for stationary purposes.




366.—Front view of Boiler.



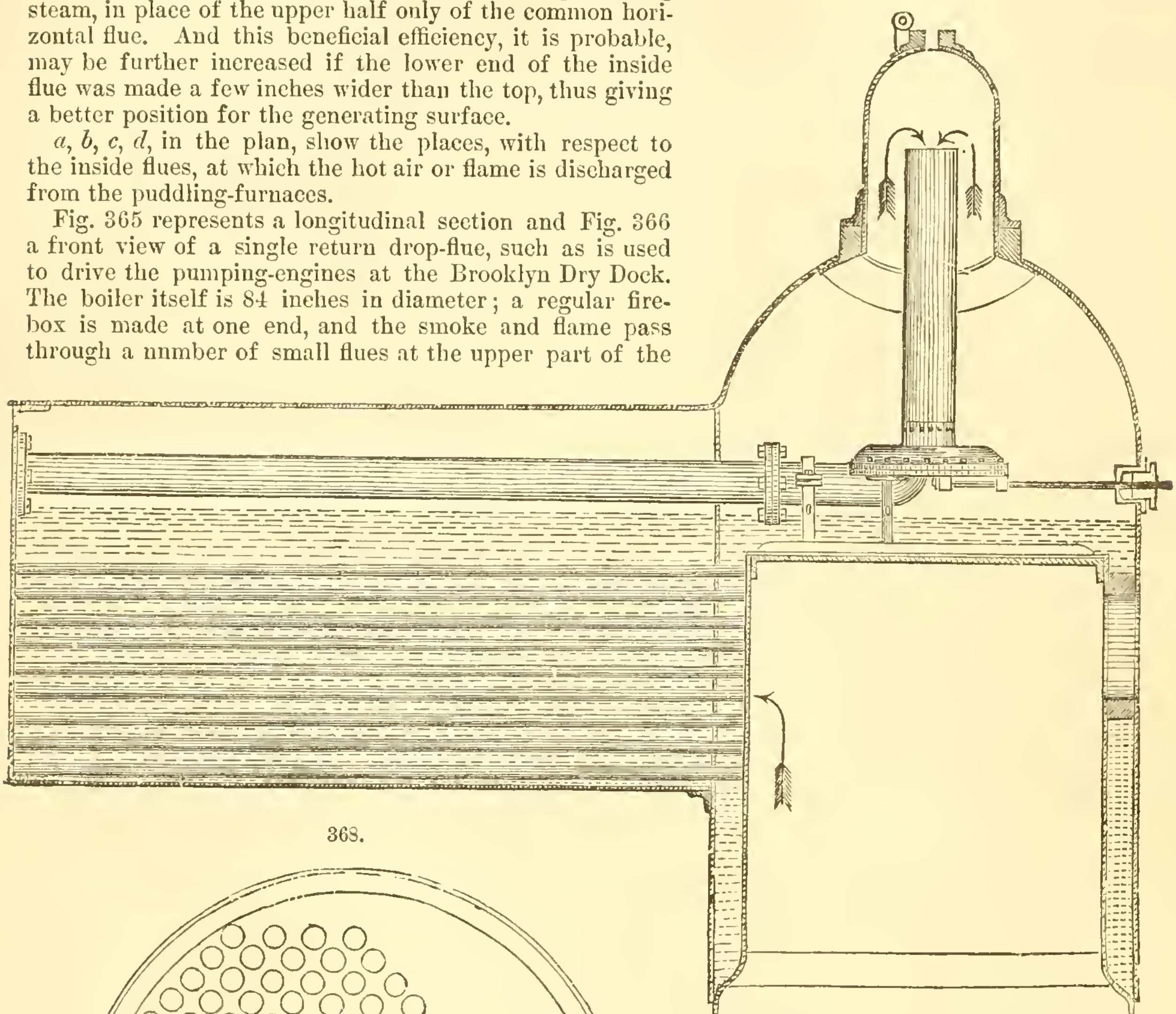

365.—Longitudinal Section of Boiler

*The Egg-shaped Boiler*, Figs. 363, 364.—This boiler is known as the "Upright Egg Boiler," and is much used in Staffordshire from the circumstance of its being so well adapted to being worked by means of the waste heats of the puddling-furnaces. Its great economy arises, in a great measure, from the vertical inside flue, the whole of the interior surface of which may be considered as effective in generating steam, in place of the upper half only of the common horizontal flue. And this beneficial efficiency, it is probable, may be further increased if the lower end of the inside flue was made a few inches wider than the top, thus giving a better position for the generating surface.

*a*, *b*, *c*, *d*, in the plan, show the places, with respect to the inside flues, at which the hot air or flame is discharged from the puddling-furnaces.

Fig. 365 represents a longitudinal section and Fig. 366 a front view of a single return drop-flue, such as is used to drive the pumping-engines at the Brooklyn Dry Dock. The boiler itself is 84 inches in diameter; a regular fire-box is made at one end, and the smoke and flame pass through a nnmber of small flues at the upper part of the box, and are returned through larger and less numerous ones at the bottom of the boiler nearly to the fire-box again, where they are taken off laterally into the chimney. All the flues, and boxes at the end of the flues, are included within the shell of the boiler. The boiler is covered with brick-work and ashes. Boilers of this form give very excellent evaporative returns, and are used much in this country both for stationary and marine purposes.

367.



368.

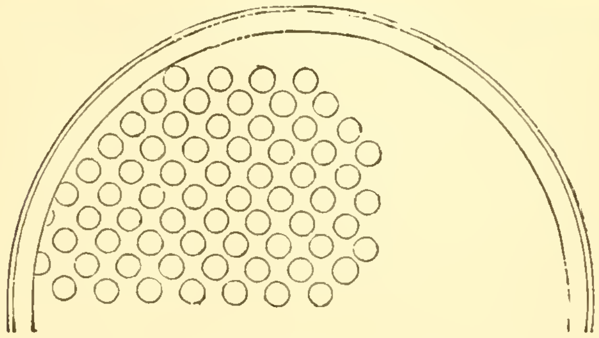


Fig. 367 represents a section of a common locomotive boiler, and Fig. 368 is an end view of one-half of the smoke end.

Figs. 369, 370, and 371, represent a boiler invented by E. A. Bourry.

The aim of the inventor of this boiler has not been to obtain an incredible saving of fuel, but to insure great safety, combined with restriction of space and cost.

*A* is a cross-section through the fire and smoke box; *B* is a front view; and *C* is a longitudinal section, showing the whole internal arrangement. The boiler consists of two cylindrical parts placed above each other; the lower part contains the fire-box, bridge-wall, and main flues; the upper one contains the return-flues, smoke-box, and steam-room. If space or convenience require it, the boiler may be made much shorter, in dispensing with the main flues, in which case the return-flues can be made of a smaller diameter. It will be seen in the engraving that the two cylinders are not entire, but are as if a slit was cut out on each of them, all the way along, and both joined there together, which leaves a free passage to both water and steam. But as, at the junction of both cylinders, the boiler would have a tendency to open outward, this is prevented by a strong iron bar being placed in each hollow, and both kept securely together by a number of traversing bolts.

Figs. 372 and 373 represent James Montgomery's improvements in steam-boilers, having in view an economical mode of using the fuel; the establishing of a perfect circulation of the water

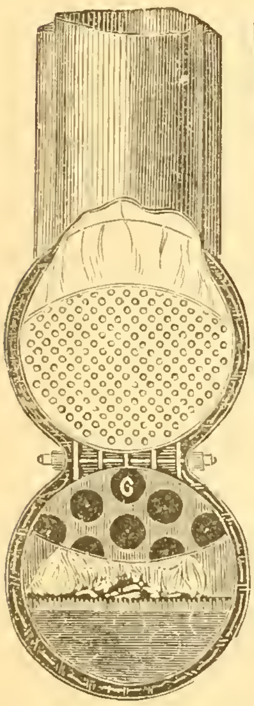
through the tubes; the depositing of sedimentary matter in a receptacle below the fire, and the preventing of the passing of water, from foaming or other causes, into the steam-pipe and cylinder.

Fig. 372 is a vertical section through the centre of the boiler, and through the furnace attached thereto.

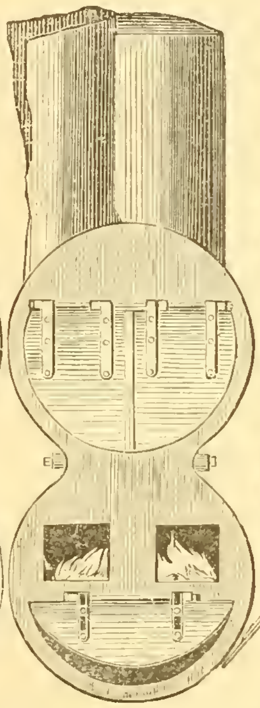
Fig. 373 is a view of a part of the boiler, supposing the furnace part to be removed, and a vertical section to be made of the sectional part in the line $XX$ of Fig. 372, and at right angles thereto.

The improvements in this patent consist in arranging the fire-chamber or furnace of a tubular

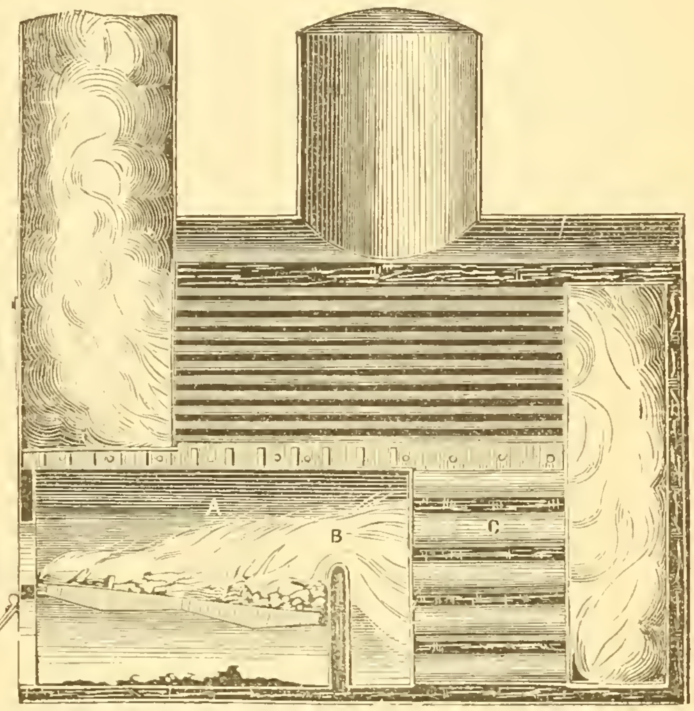
369.



370.



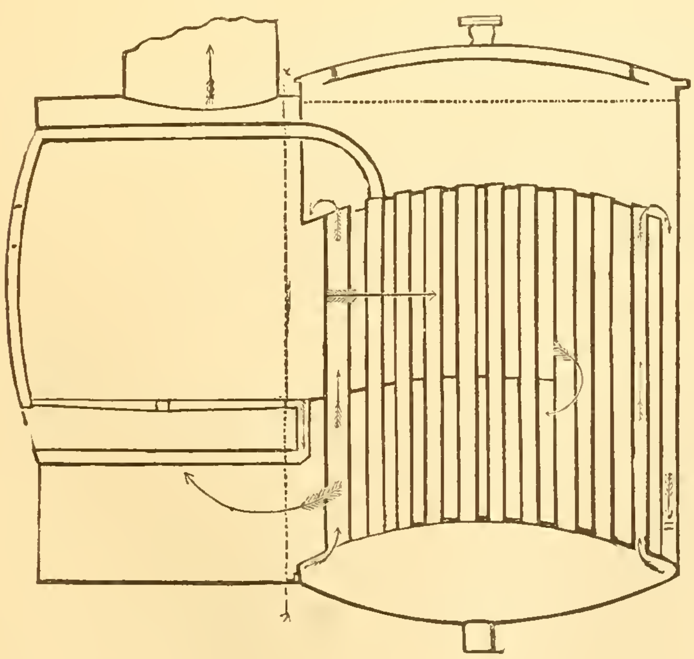
371.



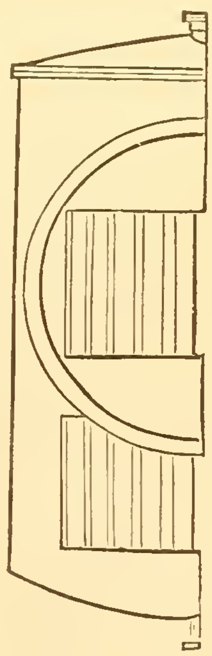

boiler at the side, so that the heat shall act on the upper half of the tubes, in combination with a diaphragm or partition, and flue to carry off the flame, heated air, etc., to act on the lower half of the tubes after acting on the upper half, as herein described.

The patentee also claims the making of the bottom of the boiler of a conical or dished form, with a mud or blow-off valve in the lowest part of the concavity, in combination with the vertical tubes

372.



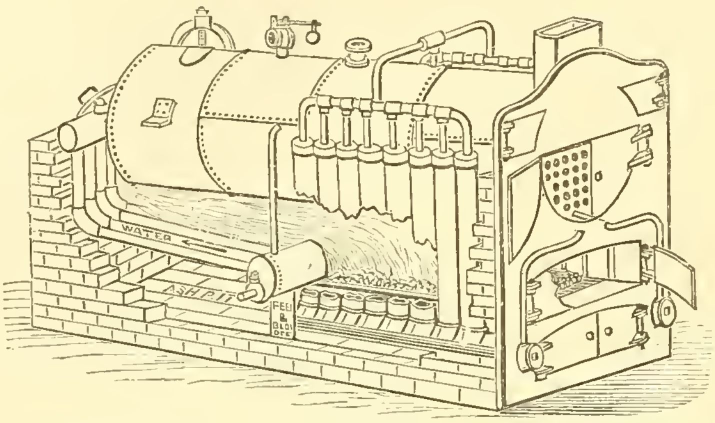
373.



communicating with the bottom in the manner herein described, to permit the deposit of the sediment, there being a water-space surrounding them to induce a circulation of the water up the tubes and down the surrounding water-space, to wash the sediment toward the mud or blow-off valve.

C. D. Smith's improvement, Fig. 374, consists in the attachment of a tubular furnace, containing water, to an ordinary tubular boiler, and thus adding some very efficient heating surface. Some

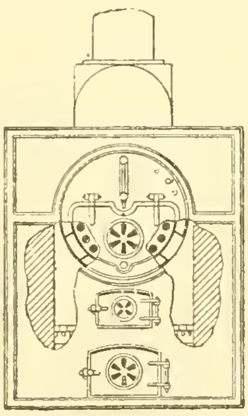
374.



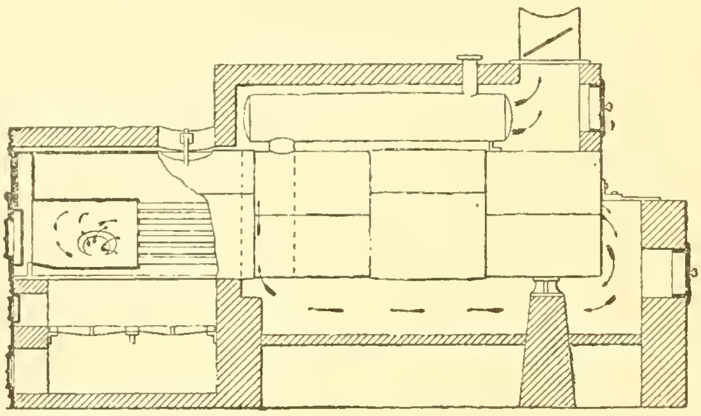

experiments made in England, with a similar attachment to a Galloway boiler, gave very favorable results. (See *Engineering*, xxii.)

The Lowe boiler, Figs. 375, 376, is built of steel. It is a tubular boiler, lengthened at the front,

375.

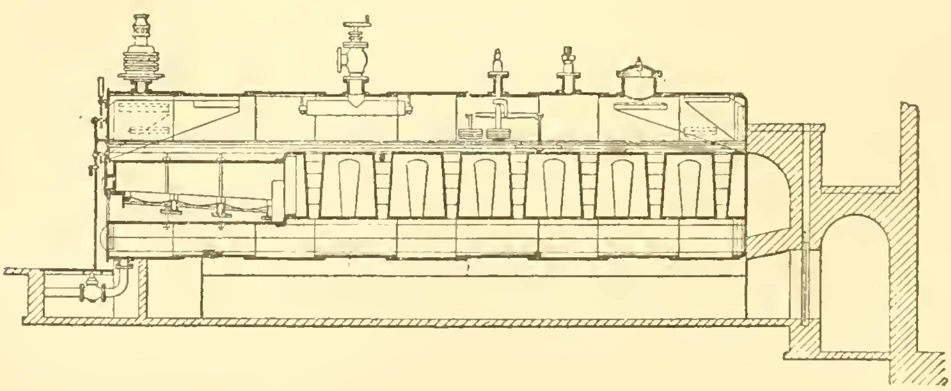


376.



so as to form a chamber into which the products of combustion pass on their way to the tubes. It has, also, a superheating drum.

377.



The Galloway boiler, Figs. 377, 378, is a cylinder with an internal flue, consisting of two furnaces at the front end, uniting into one back flue of an irregular oval form, this back flue being crossed by conical water-tubes. It is constructed of steel.

378.

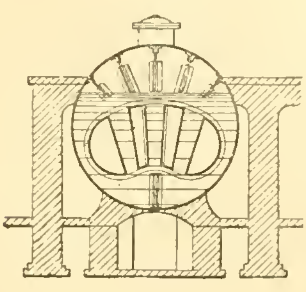
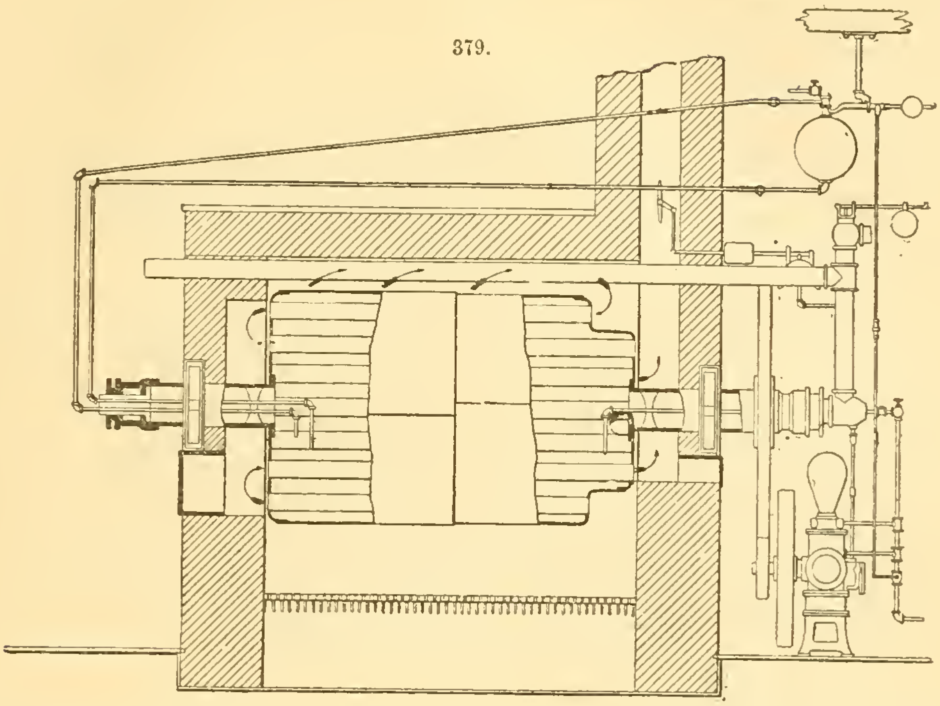


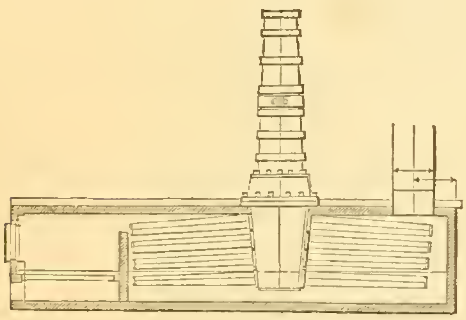
Fig. 379 illustrates the Pierce rotary boiler, which is a cylinder revolving on trunnions, directly over the furnace. Encircling cups are used around the tubes of the outer row, for the purpose of keeping them covered with water, and the tubes of the inner row are intended to form superheating surface. A comparison of an economy trial of this boiler (experiment 65, p. 205) with the mean of experiments 16 and 17, page 203, made in a boiler which did not revolve, but was otherwise in conditions approximately the same, but not as favorable, renders it doubtful whether the revolving feature is of especial advantage.

379.

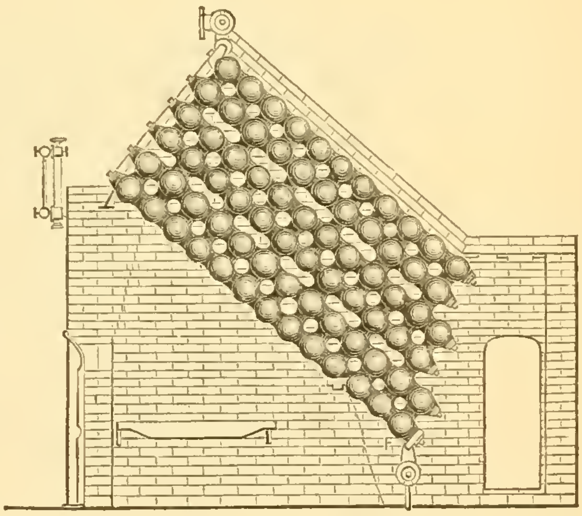


*Water-Tube Boilers.*—Figs. 380 to 388 represent sectional or water-tube boilers. The boiler, Fig. 380, used by Mr. Stevens in 1806, and now preserved in the Mechanical Laboratory of the Stevens Institute of Technology, seems to have been the earliest example of this form. The credit of being

380.

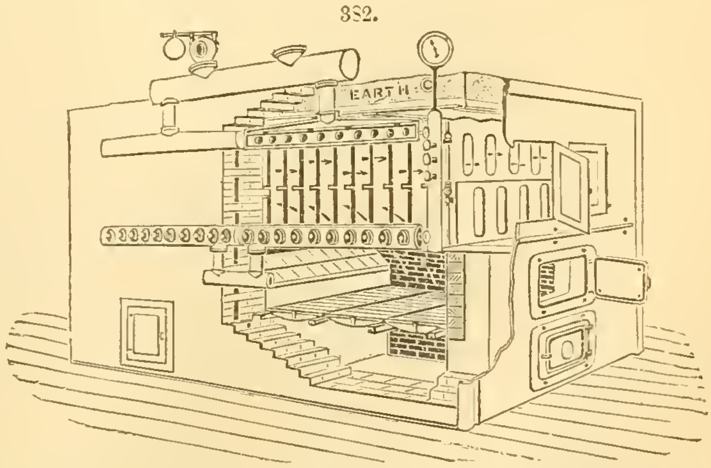


381.



the first inventor is usually given to a Mr. Moore, some 20 years later. Dr. Alban used a sectional boiler in 1849, and Perkins in 1859. The Harrison boiler, Fig. 381, was probably the first sectional boiler that was brought into general use. The reader will find descriptions of many of the earlier forms of sectional boilers in "A Practical Treatise on Boilers and Boiler-Making," by W. P. Burgh, and "The Proceedings of the Institution of Mechanical Engineers," 1865.

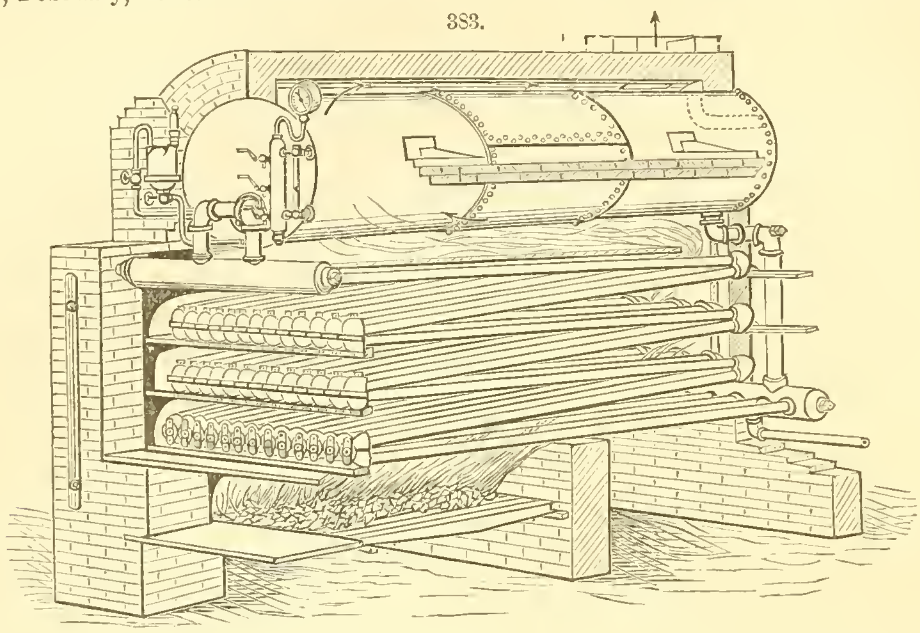
382.




The Harrison boiler, Fig. 381, is constructed of hollow cast-iron spheres, each 8 inches in diameter externally, and three-eighths of an inch thick, connected by curved necks $3\frac{1}{4}$ inches diameter. These spheres are held together by wrought-iron bolts and caps, and in one direction are cast in sets of two or four, with opposite lateral openings to each sphere, and are called by the inventor two or four ball units, as the case may be. These units connect by rebate-joints, accurately made on the edge and fitting closely, making, when drawn together, a steam and water-tight joint.

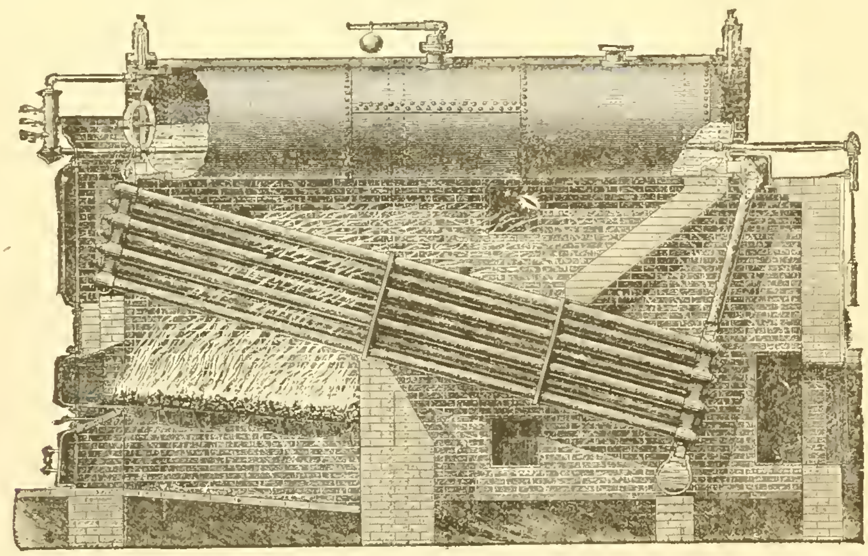
For an interesting account of experiments of the most severe character made with this boiler, by the Committee on Science and Art constituted by the Franklin Institute, see *Journal of the Franklin Institute*, February, 1867.

383.



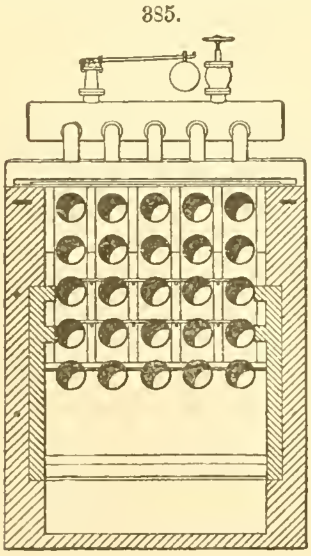
The Exeter boiler, Fig. 382, consists of a series of cast-iron sections, each of which forms a complete boiler in itself, rectangular in form, $3\frac{1}{3}$ feet long, 3 feet high, and 4 inches thick, the iron

384.

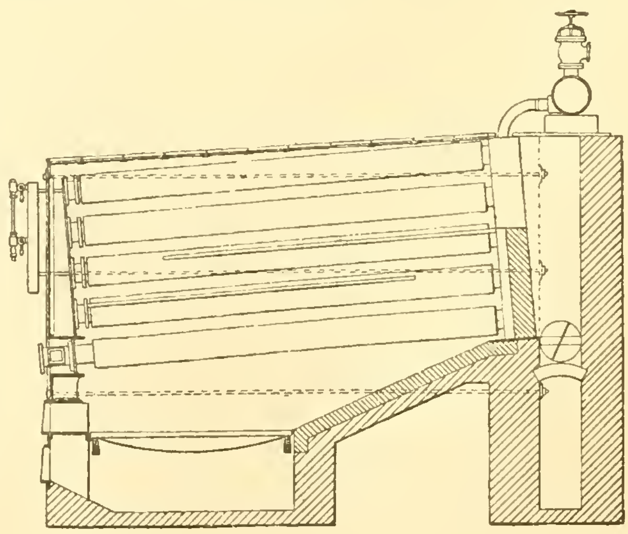


being .34 inch thick. Each section is cast with 12 openings through it, 2 inches by 12 inches. These openings form fire-tubes, and increase the heating surface, while their walls tie the flat sides

385.



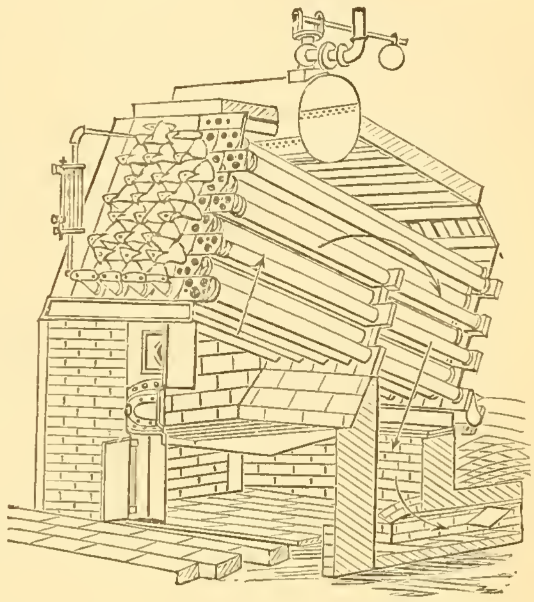
386.



of the section together. Every angle is rounded inside and out; and the bottom and top faces of each section have a wave-like form, to allow for contraction and expansion.

The sections are arranged over the fire on edge, transversely to the line of draught, with spaces of 1 inch to 2 inches between them. The lower part of each section is connected by an extra heavy 2-inch pipe extending through the wall of the setting to a main feed-pipe outside, common to all. The upper part is connected, in a similar manner, to a main steam-pipe. The main feed-pipe has plugged openings directly on line with the bottom of each section, to facilitate the cleaning of the sections.

387.



The construction of the "Acme" boiler will be rendered plain by an inspection of Fig. 383.

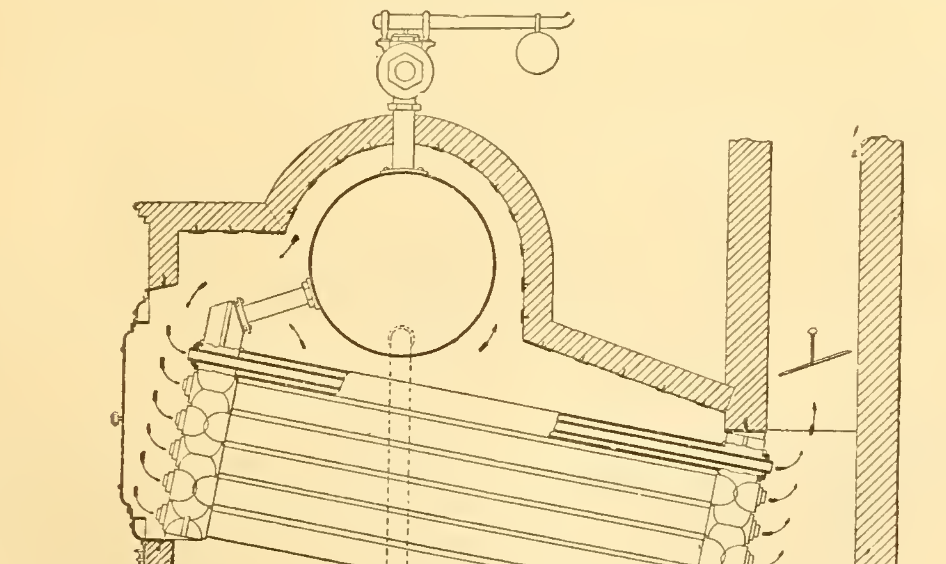
The Babcock and Wilcox boiler, Fig. 384, consists of a series of inclined tubes, connected at each end to a manifold chamber, which latter chambers are connected to one or more horizontal drums above them. By means of diaphragm plates, the products of combustion are deflected three times in their passage to the chimney.

The general arrangement of the Howard boiler, an English invention, is shown in Figs. 385, 386. A report of a trial of this boiler, comprising many interesting particulars, was published in *Van Nostrand's Eclectic Engineering Magazine*, xiv. It is, in many respects, one of the most useful reports on a boiler trial in print.

The tubes of the Root boiler, Fig. 387, are connected at each end by a series of triangular plates and crowfeet, the joints being formed by the aid of rubber grummets. Contractions are thus produced at the points of connection, with the intention of causing the separation of steam in a dry state. It will be seen, from the location of the water-gauge, that the upper rows of tubes form superheating surface.

In the Whittingham boiler, Fig. 388, the water is contained in the narrow spaces between the two tubes shown in section, and the products of combustion first pass around the outer tubes, and then through the inner ones, so that there is a large amount of heating surface, compactly arranged. The outer tubes are fitted at the ends in castings of a zigzag form The inner tubes are threaded

388.



on the ends, and secured by hollow nuts with faced collars, which also draw the outer tubes firmly to their seats when screwed up. A vertical drum of considerable size is sometimes added, thus increasing the water room.

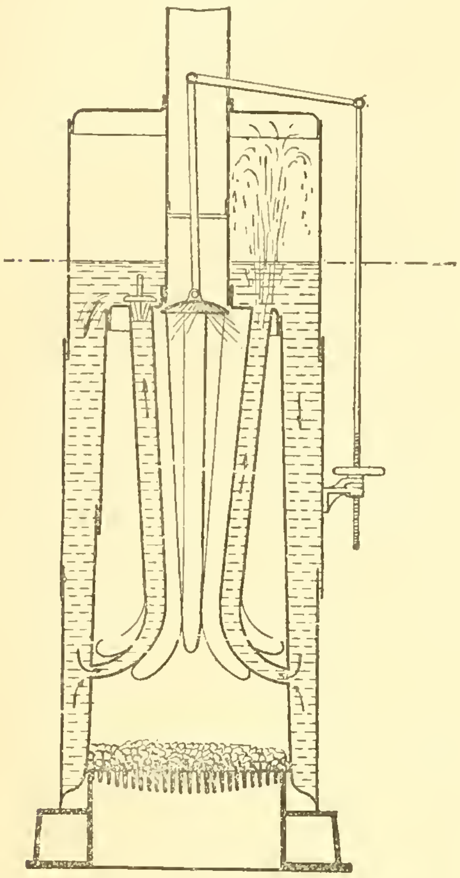
A recent form of sectional boiler consists of a coil of pipe, through which the feed-water passes by forced circulation. Great efficiency and safety are claimed for this arrangement.

*Portable Boilers.*—The boilers used in connection with portable or self-contained engines are usually of the locomotive or vertical variety. Particulars concerning their dimensions and performance will

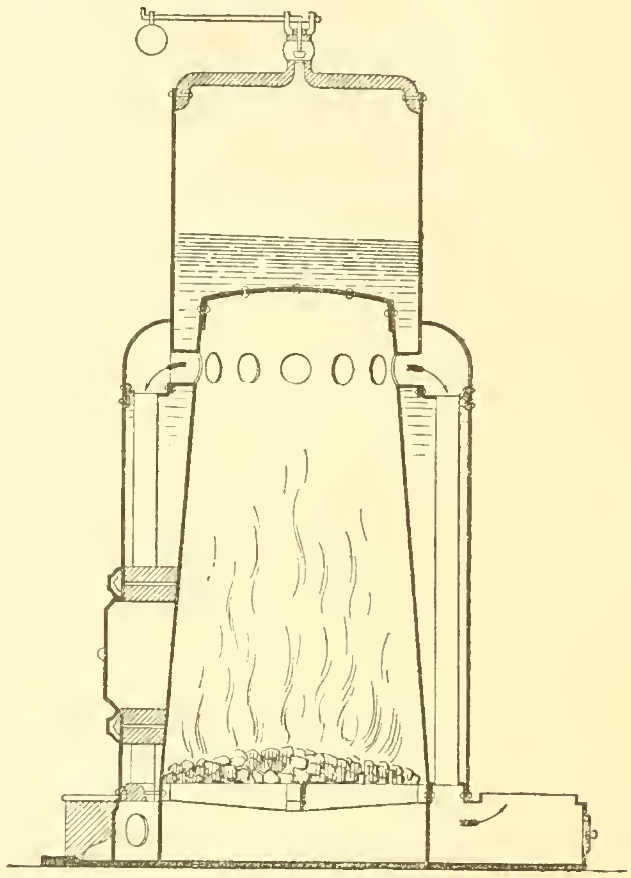
be found under the heading Heat-Engines, and in this place only one or two of the more peculiar forms are illustrated.

The Davey-Paxman boiler, Fig. 389, is a vertical boiler, having a set of bent and tapering tubes

389.



390.

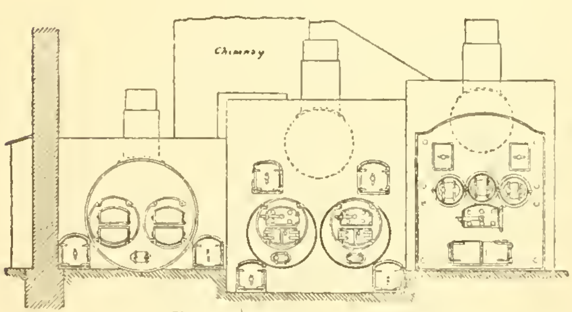


in the fire-box. Deflecting valves are placed at the tops of the tubes to change the course of the water in its circulation.

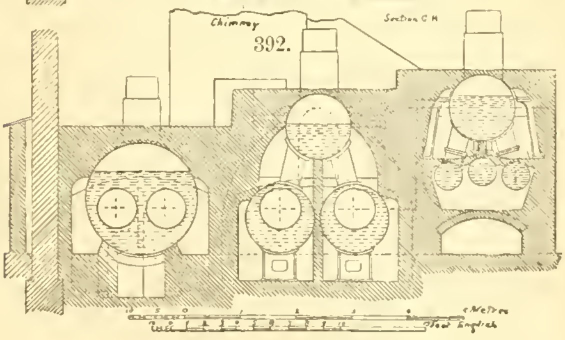
The Shapley boiler, Fig. 390, consists of two cylindrical sections, the annular space between the two containing fire-tubes being arranged radially.

The special forms of boilers used for steam fire-engines are described in the article Engines, Fire.

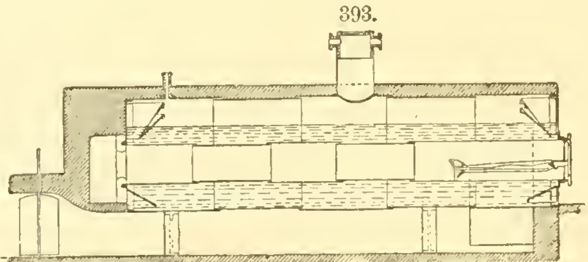
391.



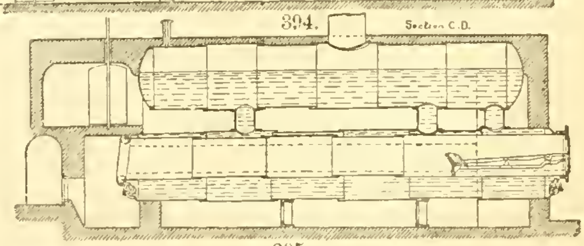

392.



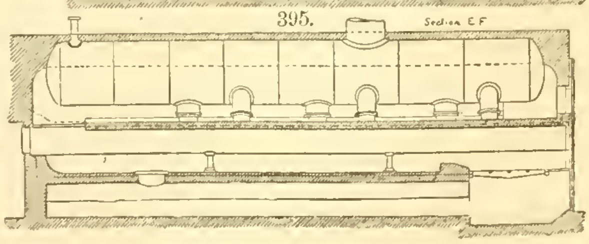

393.



394.




395.



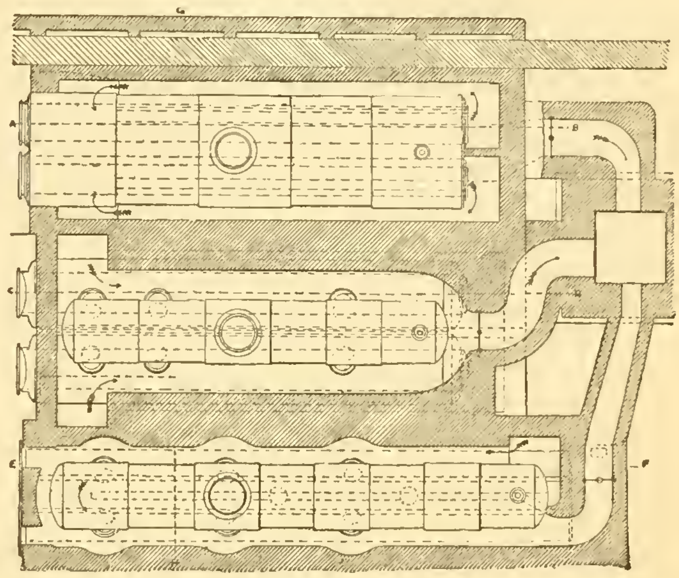

*European Boilers.*—Figs. 391 to 396 show the forms of stationary boilers largely used in England and France.

The Lancashire boiler, Fig. 393, has two flues, in which the furnaces are located. The products

of combustion pass through these internal flues, then through the side-flues to the front of the boiler, returning by the bottom flue to the chimney.

The Fairbairn boiler, Fig. 394, has three cylindrical shells, two of which contain flues with furnaces in them, the third being placed above, and connected by tubes. The products of combustion, after leaving the internal flues, return through the side and bottom flues, and pass to the chimney between the three cylindrical shells.

396.



The Elephant boiler, Fig. 395, has three small cylindrical shells, connected by tubes to the boiler proper above. The products of combustion first pass around the small cylinders, return to the front by a flue on one side of the boiler proper, and pass to the chimney through a flue on the other side. (For an account of a very thorough trial of these boilers, see the "Bulletin de la Société Industrielle de Mulhouse," 1875, an excellent abstract of which is contained in *Engineering*, xxi.)

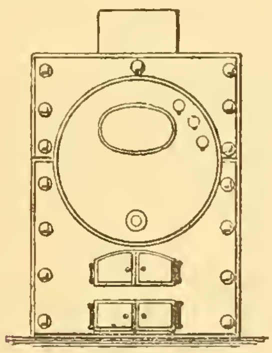
On pages 203 to 205 are the results of experiments with several of the boilers that have been described.

*Setting Boilers.*—In a majority of instances, the stationary boilers in use in this country are cylindrical, flue, tubular, or sectional, set in brickwork. Some notes in relation to the setting and fittings are appended.

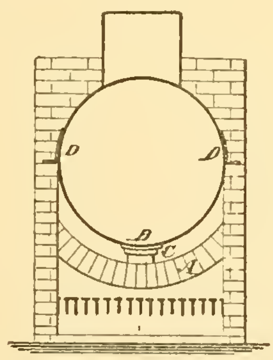
The irons usually employed in setting a boiler in brickwork are: The front, tie-bolts, bearing-bars, grate-bars, supports, damper, connection, and chimney-doors.

The front, shown in Figs. 397 and 400, should be made high enough to extend above the top of

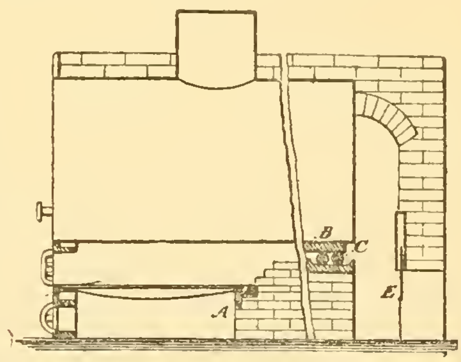
397.



398.

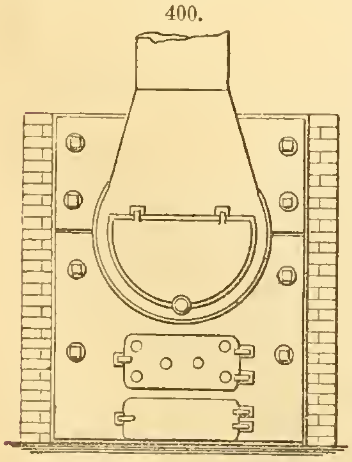



399.

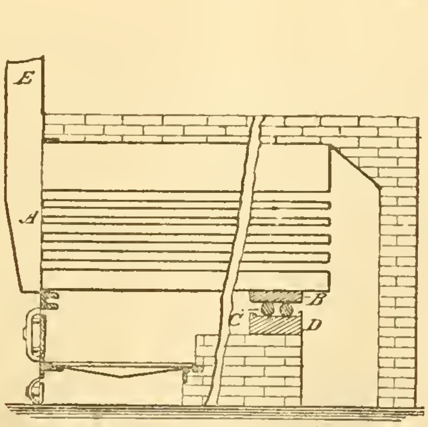



the boiler, so that the side-walls and back can also be built up and the boiler covered on top. For the sake of cheapening the price of the fixtures, some boiler-makers furnish a low front, so that, when the boiler is set, the top is left uncovered. Although this plan reduces the cost of the fixtures

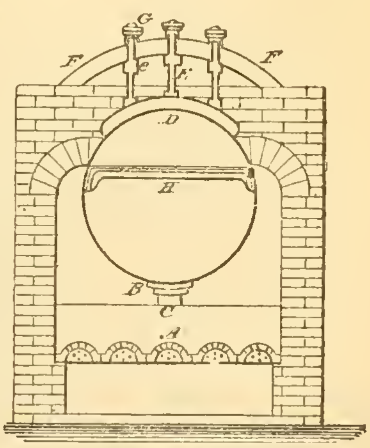
400.



401.




402.




and setting, it is the dearest in the long run, since there is a great loss of heat by radiation from the uncovered portion of the boiler.

The supports for the boiler may be of two kinds, a single support at the end for a boiler of ordinary length, and intermediate supports for a long boiler. The best form of support for the end of a boiler is shown in Figs. 398, 399, 401, and 402. The boiler rests on a cast-iron saddle, *B*,

which is supported on rollers, *C*, the latter resting on a plate, *D*, on the brickwork. By this arrangement the boiler is free to expand and contract under changes of temperature. Sometimes the boiler is supported by lugs, *D*, Fig. 398, anchored in the side-walls; but this should only be done in the case of very short tubular boilers, and the roller support is preferable for every case. Very long boilers require to be supported at intermediate points. This is commonly done by means of suspension-rods, which can be adjusted by nuts, but this practice is by no means commendable. When a fire is made under a long boiler, the bottom becomes more highly heated than the upper portion, so that the boiler tends to take a curved form. If rigid suspension-rods are used, this curving is prevented, and in many cases fracture occurs, or the boiler is said to break its back. Mr. Head, an English engineer, has devised a form of suspension-rod, which is easily constructed and effective. This is represented in Fig. 402. The suspension-rods, *E*, are attached to a plate, *D*, on the boiler, and, instead of being rigidly secured by nuts to the guard, *F*, have stiff volute springs, *G*, which keep the boiler in proper position when cold, the rods having lugs, *e*, to check the action of the springs at the proper point. Of course, when the boiler is heated, the springs will allow it to be drawn down, and it will return to its normal position when cooled. If the weight of water in the boiler is considerable, suspension from the top might produce distortion of the circular form; and to counteract this, a piece of angle-iron, *H*, may be secured within the boiler.

Tie-bolts are often used to connect the two side-walls. The ordinary form is represented in Fig. 403, the bolts passing through castings, *B*, which act as large washers.

The damper is generally a slide, as shown at *E*, Fig. 399, which is placed at the junction of the back connection or connecting-flue with the chimney. Openings should be left large enough to permit a person to enter the back connection and chimney, and these are closed by the connection and chimney-doors.

The bearing-bars are the supports of the grate-bars. The front-bearer is often cast on the front, or bolted to it, and the back-bearer is laid on the bridge-wall. In the case of long grates, an intermediate bearer is required, which is anchored in the side-walls, and supported in the middle on bricks, if the grate is also very wide. It is better, however, instead of using one wide furnace, to divide it by walls or arches into several narrow ones, both for convenience and economy in firing. Wide furnaces have sometimes been divided in this manner, after the boilers were set, producing a considerable gain of efficiency. The arrangement of the boiler front fixes the position of the grates, or their distance below the boiler. There is not a great deal of difference in the practice of boiler-makers, with respect to this distance, which is usually between 18 and 24 inches—generally nearer the former figure.

It is obvious that the iron front can be dispensed with, if desired, and the boiler sustained on brickwork alone. This is quite frequently done, but the plan does not appear to possess any special advantages, since, if the setting is properly performed, it will be quite as expensive as if the iron front were used.

The general arrangement of setting for a plain cylinder-boiler is shown in Figs. 397, 398, and 399, and calls for little remark. In the engravings, the top of the boiler is covered with brickwork; but it is a very common plan to run up the walls to a sufficient height, and fill in the space with dry earth or sand. Whichever course is pursued, the brickwork should be carried up high enough around the boiler to make a tight joint, so that none of the heated gases can escape. It will be seen that an arch is turned to form the bridge-wall. This, however, is a matter of no importance; and if it is more convenient, a horizontal bridge-wall can be built, care being taken to leave the proper opening between the wall and the boiler for the passage of the products of combustion. An average value for the proper area over bridge-wall is three-twentieths of the area of the grates; and though in practice this area is very differently adjusted by different masons, the best results are obtained when the area is an approximation to the figure given above.

In the engraving the grate-bars are set level. They are frequently dropped a little at the back, on account of some supposed advantage in firing. There is no objection to this practice, and it is extremely doubtful whether any benefit is derived from it. It will be seen that the front is secured to the brickwork by bolts, which are built into the wall, with large washers on the ends. The boiler-front, the side-walls, and the bridge-walls, should be lined with fire-brick set in fire-clay. If any pipes are brought from the boiler through the brickwork, openings should be made for them, closed with iron doors, so that they shall be readily accessible for examination and repairs. It is better, however, to attach the pipes to the front or back of the boiler, where they need not be built in.

The setting suitable for a tubular or flue boiler is shown in Figs. 400 and 401. Here the products of combustion, instead of passing from the back-connection to the chimney, return through the tubes or flues to the front-connection, *A*, and thence pass to the chimney by the flue, *E*.

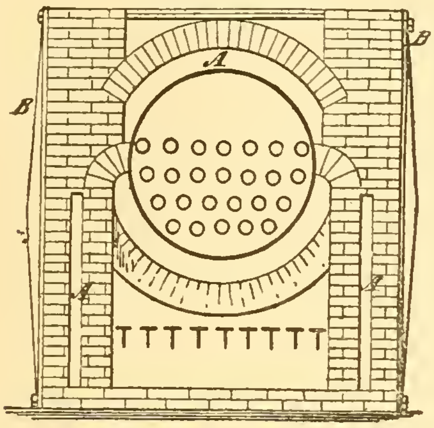
In Fig. 403 is shown the manner of setting a boiler in brickwork, with double walls and an air-space, *A*, between, to prevent loss of heat from radiation. It is much more expensive than the ordinary setting, and must be done with great care to make solid and stable walls.

The chimney may be constructed either of iron or brickwork, and made as high as is convenient. It should be at least from 40 to 50 feet, for good effect with natural draught, and can, of course, have its height increased to advantage. It is well to make the chimney with the same internal cross-section throughout, with a circular rather than a square or rectangular section, and with a smooth interior. For a square or rectangular chimney, make the section at least .17 and for a round chimney .13, of the grate-surface; and there is no harm in making it larger, since its section can easily be regulated by the use of the damper.

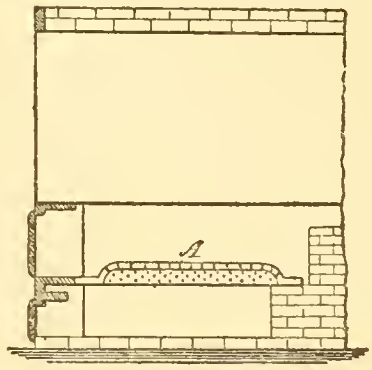
Where one chimney is used in common by two or more boilers, the flue from each should be continued for some little distance into the chimney, or else there should be a flue of large dimensions connected with the chimney, into which all the other flues discharge in such a manner as to prevent the interference of the products of combustion from the several boilers.

*Furnaces for Sawdust.*—Furnaces in which sawdust is to be used as fuel are represented in Figs. 403 and 404. The boiler should be quite short, and the grate-surface should be about twice as large as for coal. Cone-grates, of cast-iron, as shown in the figures, are used. The furnace should be set back some distance from the front, as shown in Fig. 404, leaving a flat plate, on which the

403.



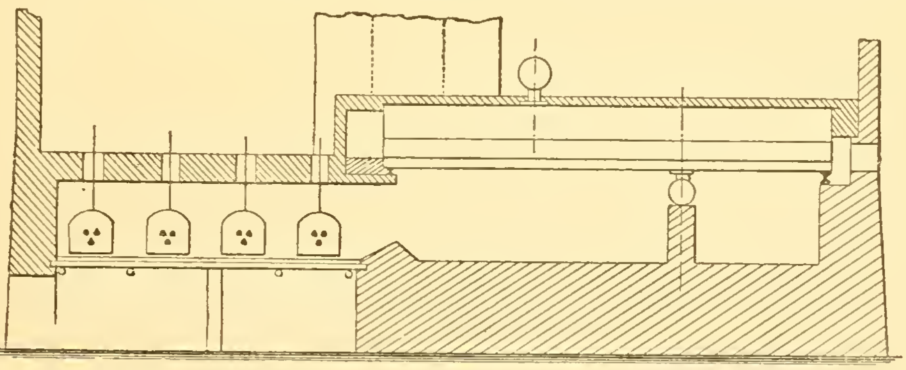

404.




sawdust is first piled, and gradually pushed upon the fire. It is generally well to have at least two distinct furnaces, which can be fired alternately. It is also necessary to have a high chimney or a forced draught.

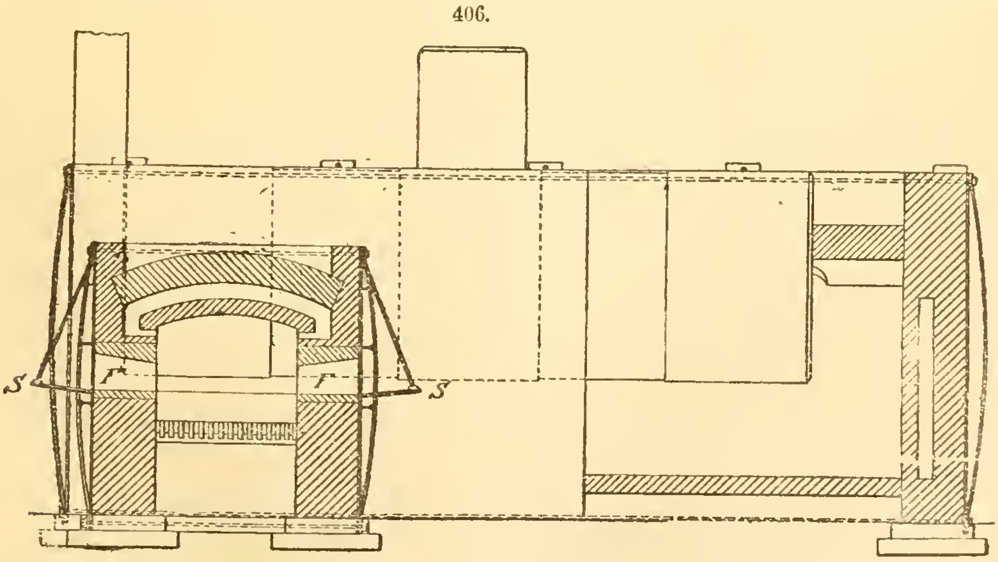
There are several special forms of furnace for burning waste material, such as sawdust and wet spent tan. One of the best designs, as constructed by Mr. J. B. Hoyt, is shown in Fig. 405.

405.



The furnace, or oven, as it is called, is near but not under the boiler, and the fuel is fed into the furnace from above, through holes, which are always covered with tan when the furnace is in operation. The question of the efficiency of furnaces using wet spent tan as fuel has been the source of extensive litigation in the courts, the voluminous testimony that was taken, however, consisting principally of theories which a few simple experiments have overthrown. The most reliable infor-

406.




mation about the performance and relative merits of detached furnaces for burning refuse material is to be found in the "Report of Theron Skeel, C. E., on the Comparative Economies of Burning Wet Spent Tan by Various Detached Furnaces." A summary of the results obtained by Mr. Skeel is appended.

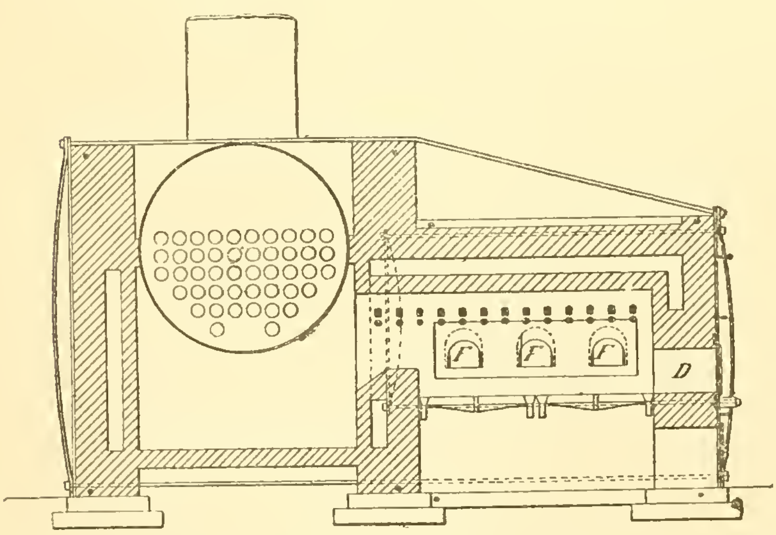
*Summary of Experiments on Wet-Tan Furnaces, by Theron Skeel.*

| NUMBER FOR REFERENCE. | WEIGHT OF A CORD OF TAN, IN POUNDS. | | Per Cent. of Water in Tan. | POUNDS OF TAN CONSUMED PER HOUR. | | | | | | POUNDS OF WATER EVAPORATED, FROM AND AT 212°. | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Total. | | Per Square Foot of Grate Surface. | | Per Square Foot of Heating Surface. | | Per Pound of Tan. | | Per Square Foot of Grate Surface per Hour. | Per Square Foot of Heating Surface. per Hour. |
| | Wet. | Dry. | | Wet. | Dry. | Wet. | Dry. | Wet. | Dry. | Wet. | Dry. | | |
| 1 | 4,442 | 1,710.2 | 61.5 | 1,675 | 645 | 27.9 | 10.7 | 4.19 | 1.61 | .893 | 2.319 | 24.7 | 3.79 |
| 2 | 4,294 | 1,571.6 | 63.4 | 2,235 | 818 | 28.7 | 10.5 | 2.69 | .98 | 1.117 | 3.025 | 31.7 | 3.36 |
| 3 | 4,225 | 1,571.7 | 62.8 | 1,440 | 536 | 18.4 | 6.8 | 1.72 | .64 | 1.192 | 3.204 | 22. | 2.25 |
| 4 | 4,275 | 1,645.9 | 61.5 | 1,419 | 546 | 18.2 | 6.1 | 1.71 | .66 | 1.605 | 4.168 | 29.2 | 2.73 |
| 5 | 4,260 | 1,606. | 62.3 | 1,376 | 519 | 10. | 6. | 1.66 | .63 | 1.48 | 3.954 | 26.1 | 2.5 |
| 6 | 4,112 | 1,686. | 59. | 865 | 355 | 5.4 | 2.2 | 1.81 | .73 | 1.68 | 4.098 | 9. | 3. |
| 7 | 4,270 | 1,917.2 | 55.1 | 3,011 | 1,352 | 12.4 | 5.6 | 1.5 | .67 | 1.988 | 4.529 | 21.2 | 2.92 |
| 8 | 4,076 | 1,581.9 | 61.2 | 2,588 | 1,004 | 13.4 | 5.2 | 2.72 | 1.05 | 1.79 | 4.613 | 24.1 | 5.19 |
| 9 | 4,076 | 1,581.9 | 61.2 | 1,942 | 1,754 | 10.1 | 3.9 | 2.04 | .79 | 2.058 | 5.304 | 20.8 | 4.26 |

| Per Cent. of Ashes. | RATIO OF | | Pounds of Air supplied per Pound of Dry Tan. | TEMPERATURES. | | REMARKS. | NUMBER FOR REFERENCE. |
|---|---|---|---|---|---|---|---|
| | Heating to Grate Surface. | Draught Area to Grate Surface. | | Furnace. | Chimney. | | |
| 2.6 | 6.66 | .042 | .... | ..... | 700° | Crocket Furnace—Flue Boiler............ | 1 |
| 2.7 | 16.4 | .071 | 22. | 1,800° | 580° | " " " " ............ | 2 |
| ... | " | " | .... | 1,900° | 420° | " " " " ............ | 3 |
| ... | " | " | 16. | 1,900° | 490° | " " " " ............ | 4 |
| ... | " | " | .... | 1,900° | 455° | " " " " ............ | 5 |
| ... | 2.9 | .019 | 18. | 1,900° | 580° | Thompson " " " ............ | 6 |
| ... | 8.2 | .034 | 10.5 | 1,900° | 510° | " " Tubular " ............ | 7 |
| ... | 4.75 | .033 | 19. | 2,000° | 700° | Hoyt " Flue " ............ | 8 |
| ... | " | " | 10. | 2,000° | 580° | " " " " ............ | 9 |

The detached furnace has also been applied, by Mr. Hoyt, to the combustion of bituminous coal, as illustrated in Figs. 406, 407. *F F F* are the feed-holes for supplying coal. The furnace-door, *D*, is only used to admit air through small holes, and to haul the fire, or clean it when necessary. It will be seen that the walls surrounding the boiler and oven are hollow, and the air is drawn through the hollow spaces into the furnace through the small holes shown in the figures. *S S* are shelves on which coal is placed before being pushed into the oven. For some results from experiments with this furnace, see page 205. Straw-burning furnaces are noticed under Engines, Steam, Portable, etc.

407.



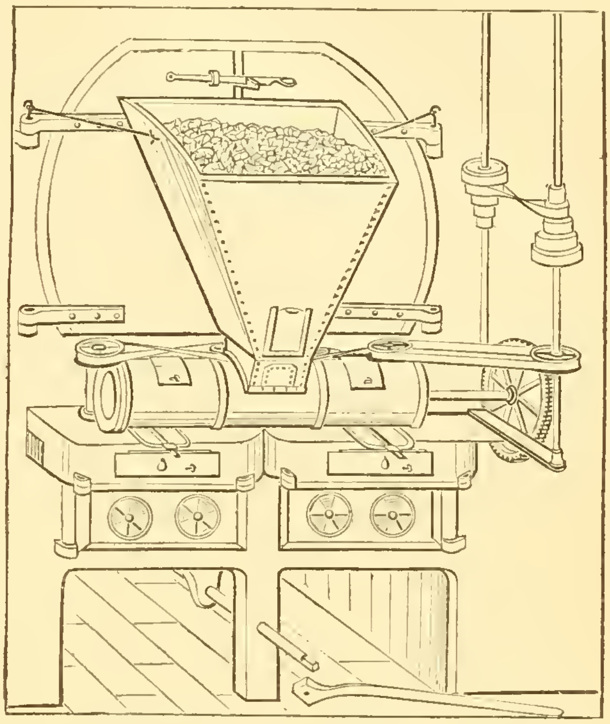

There are processes in use by which coal dust is burned directly, either by injecting it into the furnace mixed with air, over an incandescent bed of coals, or by the aid of a steam or air blast in the ash-pit. There are also patents for forming solid blocks from coal dust by pressure and the admixture of products which make the particles adhere. It has been stated that, if coal of good quality is reduced to powder, and burned by the first process noted above, more economical results will be obtained than by its use in the ordinary manner in the lump state. This view, however, does not seem to be confirmed by experiment, but, on the contrary, the ordinary method of combustion appears to be the most economical. (See *Engineering and Mining Journal*, xxi., and the "Report of the Chief of the Bureau of Steam Engineering," 1876.) Still, the process can be successfully applied to the combustion of dust, but, whether or not more economically than the second process alluded to, can only be determined by experiment. For manufacture of coal dust into blocks see the *Journal of the Franklin Institute*, February, 1874, *Van Nostrand's Eclectic Engineering Magazine*, April, 1874, and *Engineering*, September 2, 1870. See also "Reports and Awards, Group I., International Exhibition, 1876," which contains descriptions, by Frederick Prime, Jr., of the various patent fuel processes exhibited.

Mr. John E. Wooten has devised a method of burning anthracite coal dust without previous preparation. The furnace-grate has such small air-spaces as to prevent the coal dust falling through in any great quantity. A forced draught is supplied through a blast-pipe into a closed ash-pit. A steam

blower is used to produce the blast, consisting of a steam-pipe with a discharge orifice about one-tenth of an inch in diameter, discharging into the blast-pipe, which is open to the air at the outer end.

Automatic arrangements for supplying coal to furnaces are sometimes employed. Smith's Automatic Stoker, one of the most recent forms, is shown in Fig. 408. The coal is supplied to a hopper, from which it falls into a revolving crusher, and is broken to the proper size. It is dropped upon revolving disks, furnished with fans, which throw the fuel into the furnace, and distribute it evenly. The grate-bars are so arranged that they can be moved by a handle, as occasion requires, in order to keep the fire bright.

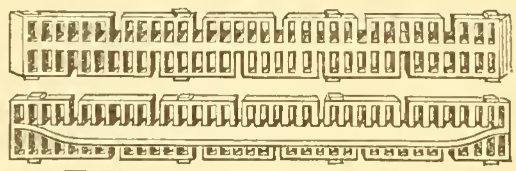
408.



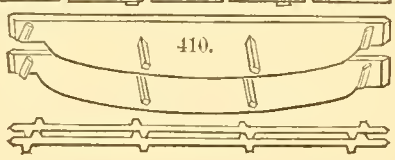
A general description of mechanical stokers may be found in the "Transactions of the Society of Engineers," 1877, and "Proceedings of the Institution of Mechanical Engineers," 1869. For an account of English practice in setting boilers, see *Engineering*, xxi., xxii.

*Grate-bars for boiler-furnaces* are ordinarily constructed of cast-iron, and should have openings for the admission of air equivalent to at least .37 of their surface. Figs. 409, 410, represent two forms of bar in common use, both of which are designed to be free from any tendency to warp, the first on account of its peculiar shape, and the second by reason of the interlocking arrangement, which is clearly shown in the figure. Water-grates, consisting of pipes through which water circulates, are sometimes employed, and grates of fire-brick have been used in special instances.

409.



410.



In burning coal, it is usually found desirable, as has already been noticed, to admit some of the air necessary for combustion above the fire. It is generally admitted through holes in the furnace-door; and sometimes, for the purpose of effecting more thorough mixture, the air is forced through the holes in small jets, mingled with steam. Prideaux's furnace-door is arranged so as to admit a varying amount of air, greatest after a fresh supply of coal is put into the furnace, and gradually diminishing as the coal becomes ignited. In the "Sixth Annual Report of the Cincinnati Exposition," there are descriptions of several special forms of furnace-doors, and accounts of experiments made with them.

*Feed-Water Heaters.*—If the products of combustion, after leaving the boiler, escape directly into the chimney, they must pass off at the temperature of the steam in the boiler, at least. By causing them to circulate around tubes or cylinders through which the feed-water is forced on its way to the boiler, their temperature can be lowered, and the heat utilized in increasing the temperature of the water. By the aid of the table on page 157 the gain by the use of heaters in the chimney, or fuel-economizers, as they are frequently called, can be calculated for any given case. Suppose, for example, that on adding fuel-economizers the temperature of the feed is increased from 60° to 180°, the pressure under which evaporation takes place being 80 lbs., the evaporation per pound of fuel will be increased in the ratio of 1.189 to 1.07, or about 11 per cent. It is to be remembered that as the addition of a fuel-economizer reduces the temperature of the products of combustion, the tendency is to diminish the draught so that a high chimney or a forced draught may be necessary. In practice a high chimney is generally employed, and the economizer is of considerable dimensions, with more heating surface than that of the boiler.

The term feed-water heater, as ordinarily used, is applied to arrangements such as coils or clusters of pipes, and cylinders, in which the feed-water is heated by the exhaust steam from a non-condensing engine. It is desirable that the passage of the steam should be obstructed as little as possible, so as to avoid increasing the back pressure, while at the same time its heat should be imparted thoroughly to the water. Heaters may either be open, as when the exhaust steam comes in direct contact with the feed-water, or the water may be forced through pipes which act as heating surfaces, being heated by contact with the steam. With the former style, the feed-water must be drawn from the heater by the pump, which must thus force hot water, while with the latter cold water can be forced by the pump into the heater, and there heated, on its way to the boiler.

Some forms of heaters are intended to purify the water as well as heat it by the use of a series of shelves or shallow basins, in which the solid material will be deposited as the temperature of the water is increased.

All natural waters hold various solid matters in solution or suspension; when in the latter state, they admit of being removed by filtration; but no system of filtration, on a scale sufficiently large to supply a moderate-sized steam-engine at a light expense, has yet come into practical use. How-

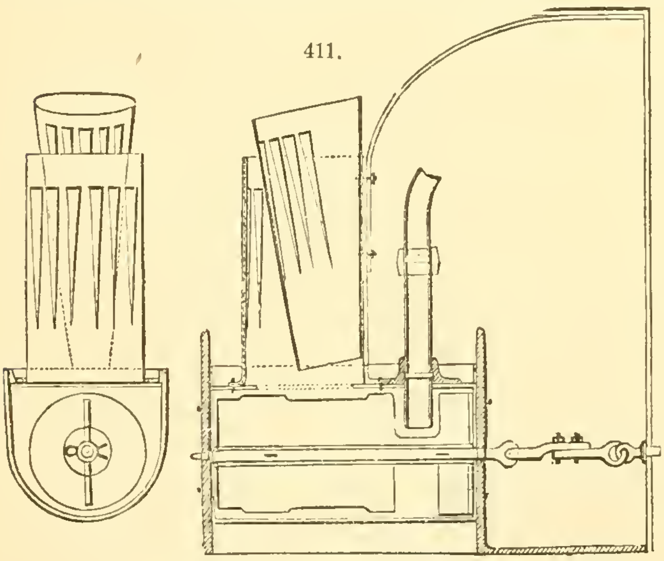
ever, it occurred to an inventor several years ago to hit upon a very simple and effectual substitute. And that was, instead of separating the water from the dirt, before passing it into the boiler, to separate and collect the dirt from the water, after it is in the boiler, by means of a series of vessels, shelves, or trays, placed up and down the boiler, constituting, in fact, so many portions of what collectively might be considered a substitute for a false bottom, upon or into which all the matters held in suspension are deposited. This, in fact, is the whole of the principle of Mr. Anthony Scott's patent of 1827, which has been so frequently repatented and reregistered since that time, like many bad copies of good pictures, some of them so very bad that the patentee, if he were living, would not know that they were even meant for imitations.

These sediment vessels operate much after the same manner as certain quiet or still places do along the banks of rivers, in causing sand or mud to accumulate in them; making so many places of shelter, where any movable matters being accidentally deposited, they remain free from agitation and not disposed to move out. In a boiler containing *boiling* water, of course the same principle prevails, the steam rising from the boiler-bottom—the sole cause of ebullition in all cases—being the agitating agent. In fact, the water never boils within the internal vessel or sediment receiver, however violently it may boil externally; and the more violently the water boils, the more rapidly the internal vessel collects all loose sediment floating about in the water. Excepting for calcareous incrustations, the process was perfectly successful in keeping a boiler clean. The only difficulty in its practical application was liability to neglect in cleaning out the collectors themselves when they got filled with deposit, and the necessity of emptying the boiler for that purpose.

For the above reasons it appeared desirable to the patentee to have his cleansing apparatus made self-acting, that is, to clean itself out, without interruption to the working of the engine, or letting down the steam; which improvement R. Armstrong effected in 1829, when the first complete boiler-cleansing machine was executed and applied to a boiler at the calico-printing works of Messrs. Thomas Marsland & Son, in Stockport, who afterward had fifteen boilers so fitted. Since the above period they have continued in general use in Lancashire.

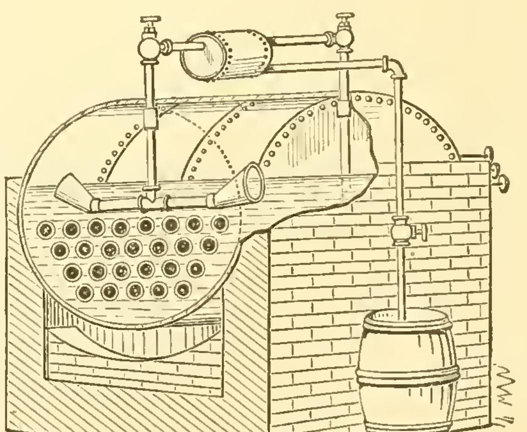
The general form of this apparatus is shown by Fig. 411. Many hundreds have been made and adapted to various kinds of boilers, including those of railway locomotives and steamboats. In the last-mentioned cases, and in all cases where there is no fire *under* the boiler-bottom, they are, generally speaking, unnecessary, except for the purpose of preventing priming, which they most effectually do when that arises from dirty water. For this purpose the upper conical-shaped vessel is made with the narrow collecting apertures adjusted partly above and partly below the surface of the water. In this way it is used by opening the valve at the end of the boiler, and putting the handle of the agitator in motion for half a minute, by which the contents of the receiver at the bottom of the boiler are discharged upward through the pipe on the right hand. This operation creates a current,

411.



SCALE.—$\frac{3}{4}$ inch = 1 foot.
Longitudinal Section and Elevation of Collectors.

412.



which draws all the scum and froth that cause the priming from all parts of the water surface into the collecting vessel and down into the receiver, whence they are discharged to the outside of the boiler by a repetition of the process.

By thus skimming the dirt from the top of the water, clean, dry steam is supplied to the cylinder of an engine instead of a mixture of steam and dirty water, causing, in ordinary cases, such great waste of power by friction on the piston and piston-rod, and unnecessary consumption of tallow.

A modern device of the same general character is shown in Fig. 412. The impurities in the water are drawn through the bell-mouthed orifices into the reservoir without the boiler, where they settle, and can be discharged from time to time into a barrel placed at the side of the boiler. The up-flow pipe is placed where the water is presumably the hottest, and the down-flow pipe, from the outside reservoir, discharges at the back end of the boiler. Bell-shaped mouth-pieces are used so that a water-circulation will take place through the apparatus near the surface of the water, with considerable variations in the water-level.

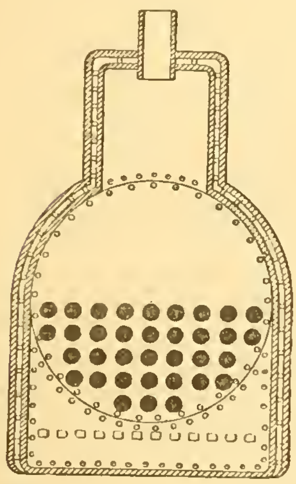
In the case of the water of the ocean, there is no practical plan of rendering the water pure before forcing it into the boiler; and where fresh water is not used as feed, it is necessary to blow off

some of the water to prevent it from becoming too highly saturated. Blowing off is sometimes performed at intervals from the bottom of the boiler, but the better practice is to maintain a continuous blow-off near the upper surface of the water in the boiler.

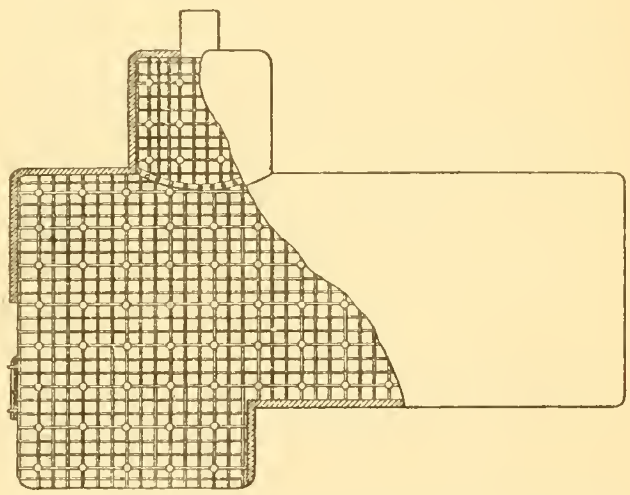
*Lamb's Blow-off Apparatus.*—In this apparatus the mouth of the blow-off pipe within the boiler is situated near the water-level, whereby it catches and removes from the boiler the particles of impalpable matter, which, by their subsidence on the flues, occasion scale.

Mr. Lamb attaches a valve to the mouth of the blow-off pipe, regulated by a float, with the view of preventing the steam from blowing off when the water has subsided below the said mouth, which is situated about 12 inches beneath the average water-line. The float is made of copper, of the form of an oblate spheroid, with a tube passing through it for the reception of a spindle, the position of which in reference to the float is regulated by nuts above and below the float, which connect with screw-threads cut upon the spindle. The valve resembles a flute-key. The lower end of the spindle is attached to the valve-arm, so as to enable the float to exert a greater power, and the upper end of the spindle moves in a guide attached to any convenient part of the boiler. By this apparatus the operation of blowing off is continuously performed; but when the salt-gauge shows that the quantity of water blown off is either needlessly great or insufficient, the position of the feed-cock is altered so as to give a diminished or increased supply. When more feed-water is admitted, the float upon the surface of the water opens the blow-off valve more widely, and permits a larger quantity of water to be blown out; and, when less feed-water is admitted, the contrary effect is produced. The operation of the float, therefore, is to maintain the water at a uniform level, and also to preserve the water within the boiler at a uniform density so soon as the right position of the feed-cock is ascertained. In boilers which are thus worked, or to which brine-pumps or any continuous blow-off contrivances are applied, an efficient salt-gauge is indispensable, as there can otherwise be no intimation of the accidental interruption of the operation, and much mischief may be the result. In the ordi-

413.



414.



nary way of blowing off, where the engineer keeps the blow-off cocks open until the water-level has descended any given number of inches, it is certain that, if the water-level descends, a certain volume of super-salted water has been ejected; unless, indeed, as has sometimes happened where there is a difference of pressure in the different boilers, one boiler has discharged its contents into the other when all the blow-off cocks are opened at once. But in the ordinary operation of blowing off one boiler at a time, a determinable quantity of water is expelled by blowing out at determinate intervals with a certainty which leaves nothing to the chances of accidental derangement, and which the use of the salt-gauge in the case of boilers fitted with any description of continuous blow-off is indispensable to insure.

415.


*Covering Boilers.*—Internally fired boilers, by which term it is intended to designate those boilers in which the products of combustion are only in contact with boiler-heating surfaces on their passage to the chimney, are generally protected from loss of heat by radiation by being covered with felting, plaster, straw, or some other material that is not a good conductor. Experiments 41, 42, page 204, show the advantage of the covering, in the case of a small boiler in an open shed. Figs. 413 to 415 represent two varieties of covering for boilers and steam-pipes. The Chalmers-Spence covering, Figs. 413 and 414, consists of two coatings of asbestos cement separated by means of wire cloth, so as to form an air-space, and the arrangement of H. W. Johns's covering, Fig. 415, will be evident from inspection. An account of some experiments, by J. C. Hoadley, on the economic effect of applying the Chalmers-Spence covering to a boiler of the locomotive type, was published in the *Journal of the Franklin Institute*, April, 1877. The following is a summary of the results obtained:

*Economic Effect of applying the Chalmers-Spence Covering.*

| | PRESSSURE OF STEAM, IN POUNDS PER SQUARE INCH, ABOVE THE ATMOSPHERE. | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 140 to 130. | 130 to 120. | 120 to 110. | 110 to 100. | 100 to 90. | 90 to 80. | 80 to 70. | 70 to 60. | 60 to 50. |
| Ratio of steam radiated to steam generated. Boiler uncovered. | 13.7 | 13.3 | 12.9 | 12.8 | 11. | 10.7 | 10.2 | 11.3 | 10.6 |
| Ratio of steam radiated to steam generated. Boiler covered... | 5.8 | 5.3 | 5.7 | 5.7 | 4.9 | 4.3 | 4.3 | 4.5 | 4.6 |
| Ratio of radiation from covered to radiation from uncovered boiler............ | 42.2 | 40.4 | 44.3 | 44.8 | 44.8 | 40.5 | 42.2 | 40. | 43.8 |

Some experiments were made by E. Burnat, in 1859, to determine the value of various materials for coating steam-pipes (see *Journal of the Franklin Institute*, March, 1875). A summary of his results is contained in the accompanying table:

*Summary of E. Burnat's Experiments on Coatings for Steam-Pipes.*

| NUMBER FOR REFERENCE. | KIND OF NON-CONDUCTING COATING EMPLOYED. | Absolute Pressure of Steam, in Pounds per Square Inch, within the Cast-Iron Pipe. | Pounds of Steam at Given Pressure, condensed by Radiation, per Hour, per Square Foot of Cast-Iron, ¾ Inch thick, in Still Air, for a Difference of Temperature of One Degree. | Thermal Units radiated per Hour, per Square Foot of Surface, under the same Circumstances, for a Difference of Temperature of One Degree. |
|---|---|---|---|---|
| 1 | The bare or uncovered cast-iron.......................... | 22.031 | 0.003024 | 2.874757 |
| 2 | The cast-iron coated with common straw, thickness of covering 1.2 inch.............................. | 22.337 | 0.001012 | 0.961814 |
| 3 | The cast-iron incased in pottery pipes coated with a mixture of loamy earth and chopped straw, around which were wound warps of common straw, there being an annular air-space between the cast-iron and the pottery pipes.............................................. | 22.337 | 0.001164 | 1.106075 |
| 4 | The cast-iron coated with cotton-waste, one inch thick...... | 22.337 | 0.001455 | 1.382632 |
| 5 | The cast-iron coated with old felt treated with caoutchouc... | 23.867 | 0.00156 | 1.478214 |
| 6 | The cast-iron coated with M. Pimont's plastic composition.. | 22.031 | 0.001657 | 1.574912 |
| 7 | The cast-iron with the same coating as in 6, painted white (the coating in both 6 and 7 was 2.4 inches thick)...... | 23.255 | 0.001539 | 1.459655 |

*Safety-Valves.*—A safety-valve, as its name implies, is designed to prevent undue pressure in the boiler to which it is attached—whence the ideal valve is one which will rise as soon as the pressure at which it is set is attained, will prevent the pressure increasing if the boiler is forced to its utmost extent, and will close promptly as soon as the pressure commences to fall. It may well be doubted, in the light of experience, whether it is possible to design a valve possessing all the above features; but they can be closely approximated, as will appear.

Before describing the forms and proportions of valves in common use, it may be well to consider questions that are constantly arising in the practice of all who have charge of steam-boilers, viz:

1. To find the pressure per square inch at which a given valve will open.
2. To find where to place the weight on a given safety-valve, so that it shall open at a given pressure per square inch.
3. To find what diameter a safety-valve must have, all the other parts being known, to open at a given steam-pressure.
4. To find the amount of opening afforded by a valve with beveled seat for any lift.
5. To find the diameter of a valve in order to give the required area of opening for a specified lift.

These problems are solved by the aid of the formulas given below:

*Notation.*

$S$ = pressure of steam, in pounds per square inch.
$D$ = diameter of valve, in inches.
$L$ = weight of lever, in pounds.
$V$ = " valve, "
$W$ = " ball, "
$l$ = distance from centre of gravity of lever to fulcrum, in inches.
$w$ = " " " ball " "
$p$ = " " " valve " "
$A$ = area of opening, in square inches, for given lift.
$v$ = lift of valve, in inches.
$h$ = depth of valve-seat, in inches.
$a$ = angle of bevel of valve-seat, or inclination to a vertical line, in degrees.

1. *Pressure at which valve will open:*

$$S = \frac{W \times w + L \times l + V \times p}{0.7854 \times D^2 \times p}.$$

2. *Position of weight:*

$$w = \frac{0.7854 \times D^2 \times S \times p - L \times l - V \times p}{W}.$$

3. *Diameter to open at given steam-pressure:*

$$D = \sqrt{\left(\frac{W \times w + L \times l + V \times p}{0.7854 \times S \times p}\right)}.$$

4. *Area of opening for given lift:*

(*a.*) For a lift less than depth of seat:

$$A = 3.1416 \times [D \times v \times \text{sin. } a + v^2 \times (\text{sin. } a)^2 \times \text{cos. } a].$$

(*b.*) For a lift greater than depth of seat:

$$A = 3.1416 \times [D \times h \times \text{sin. } a + h^2 \times (\text{sin. } a)^2 \times \text{cos. } a + D \times (v - h)].$$

5. *Diameter for given opening and lift:*

(*a.*) For a lift less than depth of seat:

$$D = \frac{A - 3.1416 \times v^2 \times (\text{sin. } a)^2 \times \text{cos. } a}{3.1416 \times v \times \text{sin. } a}.$$

(*b.*) For a lift greater than depth of seat:

$$D = \frac{A - 3.1416 \times h^2 \times (\text{sin. } a)^2 \times \text{cos. } a}{3.1416 \times (h \times \text{sin. a} + v - h)}.$$

The following table will be found useful in connection with the last two rules, and examples illustrating the application of the formulas are appended:

| ANGLE. | Sine. | Cosine. | ANGLE. | Sine. | Cosine. | ANGLE. | Sine. | Cosine. |
|---|---|---|---|---|---|---|---|---|
| 20° | .342 | .940 | 31° | .515 | .857 | 41° | .656 | .755 |
| 21° | .358 | .934 | 32° | .530 | .848 | 42° | .669 | .743 |
| 22° | .375 | .927 | 33° | .545 | .839 | 43° | .682 | .731 |
| 23° | .391 | .921 | 34° | .559 | .829 | 44° | .695 | .719 |
| 24° | .407 | .914 | 35° | .574 | .819 | 45° | .707 | .707 |
| 25° | .423 | .906 | 36° | .588 | .809 | 46° | .719 | .695 |
| 26° | .438 | .899 | 37° | .602 | .799 | 47° | .731 | .682 |
| 27° | .454 | .891 | 38° | .616 | .788 | 48° | .743 | .669 |
| 28° | .469 | .883 | 39° | .629 | .777 | 49° | .755 | .656 |
| 29° | .485 | .875 | 40° | .643 | .766 | 50° | .766 | .643 |
| 30° | .500 | .866 | | | | | | |

*Examples.*—1. A given safety-valve has a weight of 50 lbs. 24 inches from the fulcrum, the lever weighs 6 lbs., and its centre of gravity is 15 inches from the fulcrum; the weight of the valve is 2 lbs., and its centre is 4 inches from the fulcrum. The diameter of the valve is 2 inches. At what pressure will the valve begin to rise?

$$\frac{50 \times 24 + 6 \times 15 + 2 \times 4}{0.7854 \times (2)^2 \times 4} = 103.03 \text{ lbs. per square inch.}$$

2. The ball of a safety-valve weighs 100 lbs., the lever weighs 10 lbs., the valve weighs 2 lbs., and has a diameter of 3 inches. The distance of the centre of gravity of the lever from the fulcrum is 25 inches, and the distance of the centre of the valve from the fulcrum is 5 inches. How far from the fulcrum must the valve be placed, in order that the valve may open at a pressure of 100 lbs.?

$$\frac{0.7854 \times (3)^2 \times 100 \times 5 - 10 \times 25 - 2 \times 5}{100} = 32.75 \text{ inches.}$$

3. Weight of ball, 60 lbs.; lever, 7 lbs.; valve, 3 lbs. Distances from fulcrum: ball, 30 inches; centre of gravity of lever, 16 inches; centre of valve, 3 inches. Pressure of steam, 70 lbs. per square inch. What should be the diameter of the valve?

$$\sqrt{\left(\frac{60 \times 30 + 7 \times 16 + 3 \times 3}{0.7854 \times 70 \times 3}\right)} = 3.41 \text{ inches.}$$

4. The diameter of a safety-valve is $2\frac{1}{2}$ inches, the seat is three-eighths of an inch deep, and has a bevel of 25 degrees. What is the area of opening, for a lift of one-quarter of an inch?

$$3.1416 \times [2.5 \times 0.25 \times 0.423 + (0.25)^2 \times (0.423)^2 \times 0.906] = 0.86 \text{ square inches.}$$

5. The diameter of a valve is 4 inches, the bevel is 35°, and the depth of seat one-quarter of an inch. What is the area of opening for a lift of three-eighths of an inch?

$$3.1416 \times [4 \times 0.25 \times 0.574 + (0.25)^2 \times (0.574)^2 \times 0.819 + 4 \times (0.375 - 0.25)] = 3.42 \text{ sq. inches.}$$

6. A safety-valve has a bevel of 32°, and the depth of seat is half an inch. It is to lift three-eighths of an inch, and give an opening of $1\frac{1}{2}$ square inch. What should be its diameter?

$$\frac{1.5 - 3.1416 \times (0.375)^2 \times (0.53)^2 \times 0.848}{3.1416 \times 0.375 \times 0.53} = 2.23 \text{ inches.}$$

7. A safety-valve has a bevel of 33°, a depth of seat of one-quarter inch, and is required to give an area of opening of 2 inches, with a lift of half an inch. What should be its diameter?

$$\frac{2 - 3.1416 \times (0.25)^2 \times (0.545)^2 \times 0.839}{3.1416 \times (0.25 \times 0.545 + 0.5 - 0.25)} = 1.61 \text{ inch.}$$

Instead of weights, springs are sometimes employed to hold down safety-valves. The calculations, involving merely the condition that the valve shall open at a given pressure, are the same as those previously employed, except that the tension of the spring is to be substituted for the weight of the ball, this tension being first determined by experiment. Having ascertained the dimensions of a spring most suitable for a given case, it is easy to calculate the dimensions of a spring for any other case. Knowing, for instance, the cross-section of a spring adapted to one pressure on the valve, make a proportion, thus:

$$\text{Cross-section of given spring} : \text{Cros-ssection of required spring} :: \text{Pressure on first valve} : \text{Pressure on second valve.}$$

The pitch of the second spring, or the distance from the centre of one coil to the centre of the next, is found by the following proportion:

$$\text{Pitch of given spring} : \text{Pitch of required spring} :: \left\{\begin{matrix}\text{Side of a square equal} \\ \text{in area to section} \\ \text{of first spring}\end{matrix}\right\} : \left\{\begin{matrix}\text{Side of a square equal} \\ \text{in area to section} \\ \text{of second spring.}\end{matrix}\right.$$

*Example.*—It is a common practice in proportioning the parts of direct-loaded spring safety-valves to use a spring of the following dimensions: for a valve 3 inches in diameter and 100 lbs. steam-pressure, a spring made of square steel, having a cross-section of one quarter of a square inch, and a pitch of one inch, the side of a square equal in area to the cross-section being, of course, half an inch. What should be the proportions of a similar spring for a valve 5 inches in diameter, and a steam-pressure of 50 lbs. per square inch?

| | |
|---|---|
| Area of first valve | 7.07 inches. |
| Multiply by steam-pressure | 100 |
| Total pressure on first valve | 707 |
| Area of second valve | 19.64 inches. |
| Multiply by steam-pressure | 50 |
| Total pressure on second valve | 982 |

To find cross-section of required spring:

0.25 : cross-section of second spring :: 707 : 982.

and, by the rule for proportion, the product of the two extremes (245.5), divided by the third term (707), will give the second term. Now, 245.5 divided by 707 is 0.34724 inch, which equals cross-section of second spring. The square root of 0.34724 is 0.589 +, and this is the side of a square equal in area to cross-section of second spring.

To find pitch of second spring:

1 : pitch of second spring :: 0.5 : 0.589.

Here we solve the problem by multiplying 1 by 0.589 and dividing the product by 0.5, which gives 1.178 inch for the pitch of second spring.

In order to determine how large a safety-valve is required for a given boiler, the maximum evaporation of the boiler must be known. This, of course, can only be determined by experiment for any special case, but the following numbers can be safely used in general practice: The number of pounds of water evaporated per hour is equal to the area of the grate in square feet multiplied by

135, for stationary and marine boilers with natural draught;
210, for stationary and marine boilers with forced draught;
600, for locomotive boilers.

Numerous experiments have been made to determine the opening required to discharge a given weight of steam per hour, and the following rule, while not absolutely correct, gives results that can be used with confidence:

$A$ = Area of opening, in square inches.
$W$ = Weight of steam, in pounds, to be discharged per hour.
$P$ = Absolute pressure of steam, in pounds per square inch.

$$A = \frac{W}{51.43 \times P}.$$

*Example.*—Suppose that a boiler evaporates 2,000 lbs. of water per hour, what should be the area of opening afforded by the safety-valve, so that the pressure shall not exceed 100 lbs. per square inch?

$$\text{Absolute pressure} = 100 + 14.7 = 114.7.$$

$$\frac{2{,}000}{51.43 \times 114.7} = 0.339 \text{ square inch.}$$

When a safety-valve is raised by the pressure of the steam in a boiler, it usually exposes a greater area to the pressure. Hence, if the valve were loaded with a weight, it might be expected that it would open wide at once from the unbalanced pressure due to the action of the steam on the increased area. It is found in practice, however, that the ordinary safety-valve only rises very

slightly when the pressure for which it is set is reached, and that it is necessary for this pressure to be increased considerably to raise the valve much higher. With the opening of the valve, steam begins to escape from the boiler with a high velocity, and in its escape it has to overcome the resistance afforded by the opening. In this way its pressure is reduced near the orifice, so that, although there is a greater area of valve to be acted on by the steam, the pressure is reduced. How much the pressure will be reduced in any given case can only be determined by experiment, since the data for a theoretical calculation cannot be given. Some experiments made in England showed that in the case of a 3-inch valve, relieving a boiler at a pressure of 100 lbs. per square inch, the pressure under the valve was 25 lbs. per square inch. It is probable that the pressure under a valve, when opened, will vary with the form of valve and the pressure in the boiler, as a change in the valve may vary the resistance opposed to the escape of steam, and a change of steam-pressure effects a corresponding change in the velocity with which the steam issues from the orifice.

In the case of a safety-valve kept down by a spring, it must be evident that, unless arrangements are made for increasing the upward pressure, when the valve is opened it will lift but slightly, since every increase of lift requires additional force for the extension or compression of the spring. But in whatever manner the valve is loaded, it would seem that the first step in proportioning it would be to find what pressure is acting when the valve is opened. It will then be possible, knowing the resistance that must be overcome to give the desired lift, to afford such an increase of area in the open valve that the steam-pressure will balance the resistance. It must be remembered in this connection that it is desirable to have the valve close promptly as soon as the pressure is reduced; and unless some special provision is made for this, the valve, though it may open wide from the pressure due to the increased area, will be prevented, from the same cause, from closing until the pressure is greatly reduced

Numerous special forms of safety-valves have been devised, some of which are illustrated below. More extended description, with records of experiments, are to be found in the Report of the Commission appointed by Congress to examine life-saving inventions, 1868, "Transactions of the Institution of Engineers in Scotland," xvii., xviii., and "Report on Safety-Valve Tests by a Special Committee of the Board of Supervising Inspectors of Steam-Vessels," 1877. A large number of special forms of valves were tested by the latter committee, and their report contains much useful information.

416.

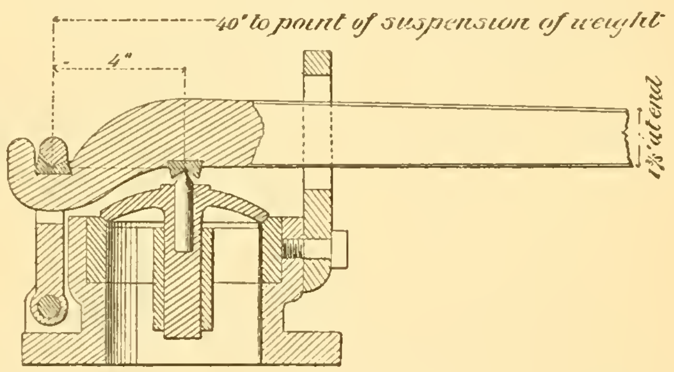



Fig. 416 represents an ordinary lever safety-valve designed by the committee, to be tested in connection with the other valves. It will be observed that the arrangement is such as to insure prompt action and freedom from sticking.

By observing the lifts of the ordinary valves, when discharging at different pressures, the committee obtained the following rule for calculating the area of valve that will give the required area of opening for any particular case: Multiply the number of pounds of water evaporated per hour by 0.005; the product will be the area of the valve in square inches. This rule gives a smaller area than the similar formula proposed by the late Prof. Rankine, in which the multiplier is 0.006. It is to be remembered that the valves used by the committee were constructed especially for the experiments, and may have acted more effectively than the average; so that the multiplier given by Prof. Rankine will probably be safer for general use. It may be added that rules of this form are the only safe ones for general use, the ordinary formulas giving very discrepant results, as shown by the following example in the report: The area of safety-valve required for the boiler on which the experiments were made, at a pressure of 70 lbs., would be: For the rule of United States Board of Supervisors, 37 square inches; for that of the English Board of Trade, 11.8; for that of the French Government, 6.75; for that given by Molesworth, 18.88; for the first rule given by Prof. Thurston, 8.3; for the second, 29; for that given by Rankine, 12; for that proposed by committee, 10. Attention has been directed to the discrepancies of these rules on several occasions; and in spite of the distinguished authority on which they rest, it is reasonable to hope that all but the last two will speedily find the oblivion they so justly deserve.

The committee observed that, when very large valves of the common form are used, their action is not satisfactory, as at high pressure the lift is scarcely noticeable, the pressure being relieved by a kind of tilting of the valve; and they fix the limit at valves having an area of 10 square inches, recommending that two or more valves be used, when a greater area than 10 inches is required.

The valves offered for test were divided by the committee into six classes, according to their construction:

1. Reactionary safety-valves, in which the escape of the steam is opposed by a lip or stricture, with the idea that the reaction will force the valve farther from its seat. One form of this class is shown in Fig. 417.

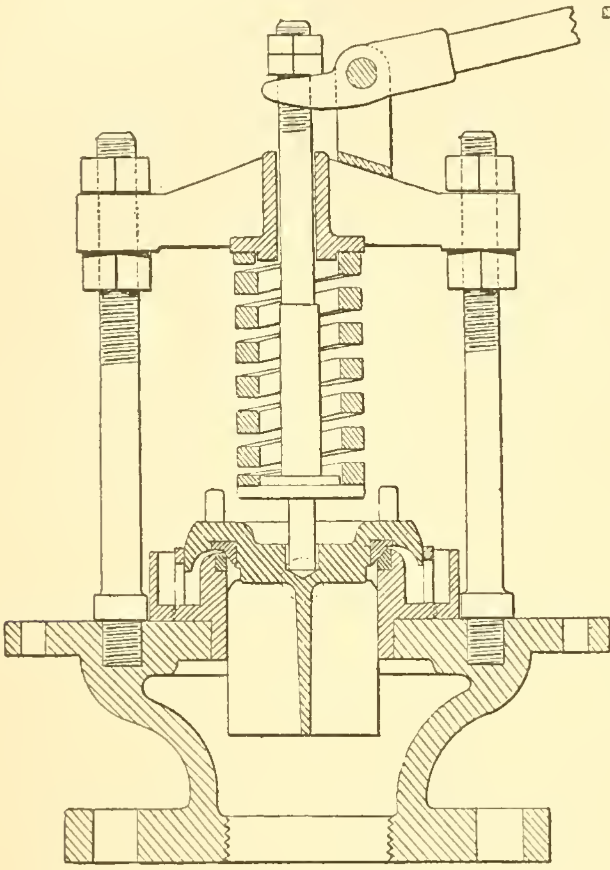
2. Disk safety-valves, in which a disk is secured to the valve having a greater area than the valve, so as to force the valve farther from its seat when it opens. Fig. 418 is an example of this class.

3. Annular safety-valves, with two seats upon an annular opening (as shown in Fig. 419), with a view of obtaining a greater area of opening for a given lift.

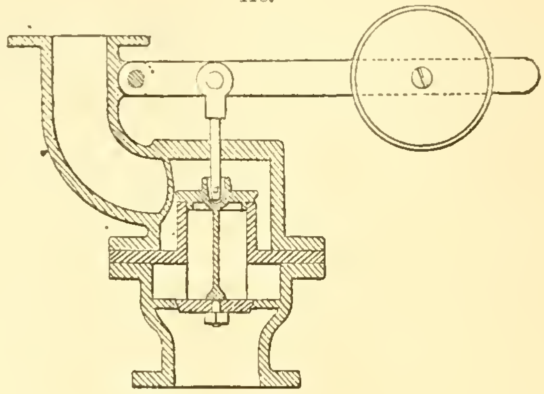
4. Double-seated safety-valves, of the same general form as the double puppet-valve, the upper and lower parts being of different areas, so that they move easily and expose large areas of opening. See Fig. 420.

5. Combination safety-valves, which are assisted in their operation by small auxiliary valves or a combination of levers. One of this class is shown in Fig. 421.

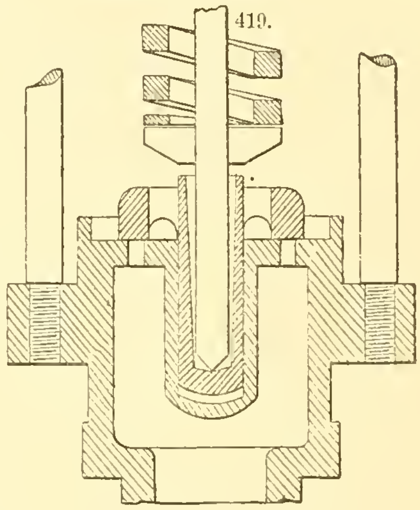
417.



418.



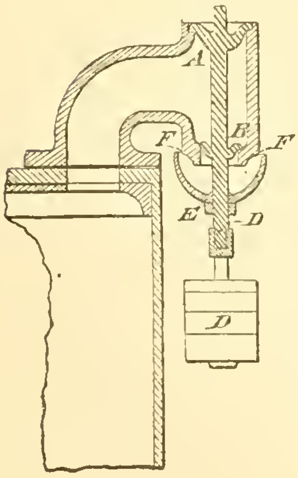
419.



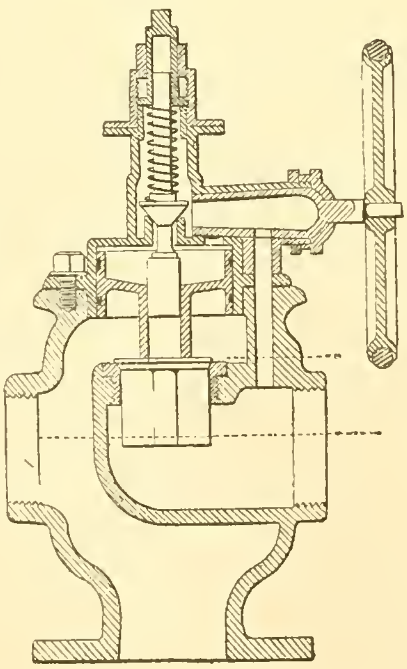
6. Piston safety-valves (see Fig. 422 for an example of this class), in which a piston connected with the valve assists it to rise.

A uniform method of test was adopted for all these valves. Each was attached, in turn, to the boiler, was set to blow off at 30 lbs., and was allowed to operate for 10 minutes, with a strong fire

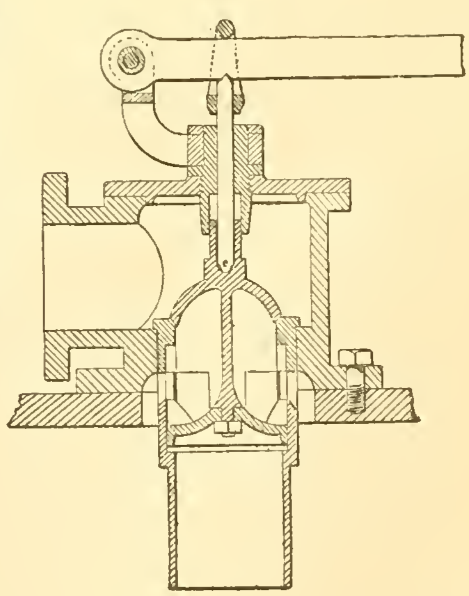
420.




421.



422.



in the boiler, was then set to 70 lbs. pressure, and the experiment was repeated. The following table gives a summary of the results obtained with 12 of the competing valves, and 2 of the common valves constructed by order of the committee. The table in the report contains results of the list of

22 valves, but the data were only complete in the case of 12, as the area of opening was not observed for the others, or they were tested at different pressures.

| NUMBER FOR REFERENCE. | Name of Valve. | Area of Valve in Square Inches. | Class of Valve. | SET TO OPEN AT 30 POUNDS. | | | | SET TO OPEN AT 70 POUNDS. | | | | NUMBER FOR REFERENCE. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | No. of Trials. | Greatest and Least Excess of Pressure. | Greatest and least Area of Opening in Sq. Inches. | Greatest and Least Closing Pressure. | No. of Trials. | Greatest and Least Excess of Pressure. | Greatest and Least Area of Opening in Sq. Inches. | Greatest and Least Closing Pressure. | |
| 1 | Ashcroft...... | 5 | Reactionary. | .. | ...... | ...... | ...... | 2 | 0 | 1.231 | 65½, 67¼ | 1 |
| 2 | Crosby........ | 5 | " | 5 | 5¼, 2½ | 1.257 | 26½, 29 | 5 | 4, 3 | .729, .628 | 64, 68¼ | 2 |
| 3 | Chamberlain .. | 5 | " | 2 | 7, 6¾ | 1.580 | 27¼, 28 | 1 | 9¼ | .92 | 67½ | 3 |
| 4 | Hodgin........ | 5 | " | 2 | 6, 0 | 2.934 | 20¼, 26 | 2 | 0 | 1.427 | 55½, 56 | 4 |
| 5 | Orme.......... | 5 | " | 1 | 16 | .457 | 30 | 1 | 4 | .284 | 61 | 5 |
| 6 | Richardson..... | 5 | " | 5 | 7, ¼ | .869, 1.455 | 27½, 29½ | 3 | 3¾, 1¼ | .691 | 66¼, 68 | 6 |
| 7 | Borden........ | 7 | Combinati'n | 2 | 2, 0 | 1.11 | 17, 26 | 4 | 4, 1 | .574 | 60, 67½ | 7 |
| 8 | Clement....... | 5 | " | 3 | 1¼, ½ | 1.171 | 27¼, 29 | 4 | ½, 0 | 1.171 | 64¼, 70 | 8 |
| 9 | Cockburn...... | 5 | Disk ....... | 2 | 0 | 1.82 | 27 | 2 | ¼ | 1.18 | 67¾, 68½ | 9 |
| 10 | Lynde ........ | 5 | " ....... | 2 | 4½, 1½ | 1.11 | 26½, 29 | 5 | 0 | .555 | 65, 69¾ | 10 |
| 11 | Morse........ | 6 | Annular..... | 1 | 0 | 1.42 | 27 | 3 | 0 | .84 | 59½, 69½ | 11 |
| 12 | Rochow....... | 5 | Piston...... | 3 | 1¼, ¾ | 1.231 | 25½, 28½ | 5 | 4, 3 | 1.231 | 60½, 66 | 12 |
| 13 | Common, lever | 5 | Committee's valves. | 2 | 7¼, 4½ | .929 | 28 | 1 | 5¼ | .633 | 68 | 13 |
| 14 | " " | 10 | | .. | ...... | ...... | ........ | 1 | 2 | .725 | 68¾ | 14 |

It will be observed that some of the special forms of valves, with considerably larger areas of openings than the common valves, allowed the pressure to increase as much or more. This is probably due to the fact that the very form by which the greater lift was obtained made it more difficult for the steam to escape, and thus rendered a larger opening necessary to discharge the same quantity of steam. In the case of several experiments with the same valve, where the table shows considerable differences in the results, these were generally due to lack of adjustment, so that the best results represent the action of the valve when properly adjusted. This remark applies both to the common and special forms of valves. There is one peculiarity, quite an important one, which the table does not show, but is noted in the records given in the case of each experiment.

With the common valves, when the valve opened, the pressure gradually increased to the maximum, when the boiler was forced; and when the pressure was allowed to fall, it closed at the points indicated. With nearly all the other valves, however, after the valve opened, the pressure fell below the opening point, the valve sometimes closing several times, and the pressure falling below the opening point several times, in the course of a 10 minutes' trial; and sometimes the pressure fell at once and the valve blew off at a less pressure than that at which it was set, during the whole trial. It is evident that this is not a desirable feature in a safety-valve, if safety can be secured without this loss; and the records of the trial seem fully to confirm the opinion stated in the report, that the common valve, represented in Fig. 416, is not excelled in any important particular by its competitors—at least for stationary purposes. For use upon locomotives, and steamers in rough water, some of the special forms may be advantageously employed, and the committee especially recommend three, constructed on the reactionary principle, viz: Ashcroft's, Crosby's, and Richardson's (Nos. 1, 2, and 6 in the preceding table). It is believed that these recommendations are justified by experience.

The results of such experiments as have been described are not utilized in general practice as fully as they should be, and there are many valves attached to boilers that are only safety-valves in name.

There is a simple experiment that every one who uses a safety-valve can make, to see whether he has a valve that is proportioned to give the proper lift. Let him secure a cord to the lever or stem of the valve, so that it can be opened by hand if necessary. (Indeed, it may be said, in passing, that some convenient arrangement should always be fitted for opening the valve by hand, and it should be used at least once a day, to keep the valve in working order.) Then, by shutting off steam from the engine or wherever else it is used, and making up a good fire in the boiler, he can determine in a very short time whether or not he has a *safety*-valve; and if it will not relieve the boiler automatically it will be easy to give a larger opening by hand, so that the experiment will not be attended with danger. This simple experiment is earnestly recommended to every steam-user; for with a good safety-valve in working order, the chances of a disastrous boiler-explosion are greatly diminished.

The best manner of loading a safety-valve has been the subject of animated discussion among engineers. The opinion of the majority can be summed up as follows:

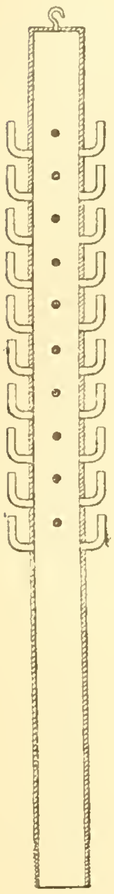
Safety-valves for the boilers of locomotives and steamers, and in all cases in which they will be subjected to oscillations and jars, should be loaded with springs. For stationary boilers, either weights or springs can be used at pleasure. In employing a spring it is generally considered best to arrange it so that it shall be compressed, rather than extended, when the valve is raised.

*Noiseless Exhaust.*—The noise caused by the escape of steam from a valve through the exhaust-pipe, and the sound of the exhaust from non-condensing engines, are frequently objectionable. Figs. 423 and 424 represent Shaw's exhaust-nozzles, for causing quiet escape and exhaust, which are said to be very effective. The construction will doubtless be evident from the figures. In Fig. 423 it will be noticed that the steam, instead of escaping from the end of the pipe, is discharged through numerous small openings. In Fig. 424 the steam escapes between coils of wire, by which, in the language of the patentee, "all the noisome vibrations are absorbed upon the coils of wire."

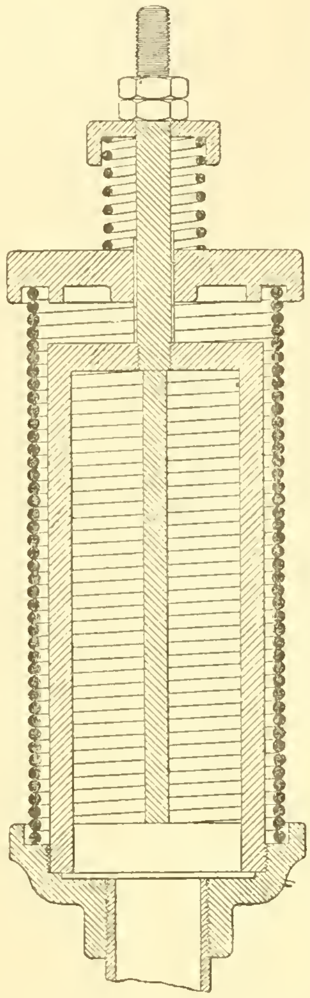
*Water-Gauges.*—The following are common varieties of water-gauges: the first the ordinary gauge-cock, the second the glass gauge, and the third the float. The gauge-cock, on being turned, shows whether it is water or steam that exists at the level at which it is inserted. There are usually three gauge-cocks inserted in each boiler, at different levels; and the rule is, to so feed the boiler that there will be steam in the top gauge-cock, and water in the other two. The glass gauge consists

of a glass tube set in front of the boiler, communicating in its superior portion with the steam-space, and in its inferior portion with the water within the boiler, the position of the tube being so adjusted that the water-level stands at about the middle of its length. The tube is connected at the top and bottom to the boiler by means of sockets furnished with cocks, so that the tube may be blown through by the steam to clear it, and the water and steam may be shut off if the glass breaks. It is unsafe to trust to the glass gauges altogether as a means of ascertaining the water-level, as sometimes they become choked, and the water continues to stand high in the tube though it may have sunk low in the boiler. If the boiler be short of steam, however, and a partial vacuum be produced, the glass gauges become of essential service, as the gauge-cocks will not operate in such a case, for, though opened, neither steam nor water will come out, but air will rush in. This sometimes occurs in practice, and glass gauges are then found to be of especial value.

423.



424.



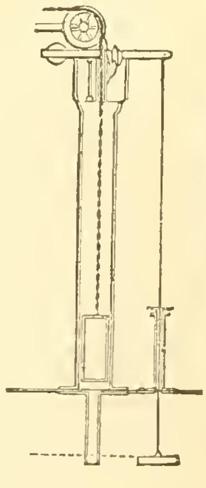
The float-gauge consists of a float resting on the surface of the water, and communicating with an index, so that the fluctuations in the water-level are, by reference to this index, made apparent. The float is usually of stone or cast-iron, but is so balanced by a counter-weight as to make its operation the same as if it were a buoy of timber. In land-boilers a float is sometimes employed to regulate the admission of the feed-water, and the same float may also indicate the height of the water within the boiler. The feed-water is admitted from a small open cistern at the top of the stand-pipe, as shown in Fig. 425. At the bottom of the cistern is a valve, which the float opens or closes, and into the cistern the water is poured by the feed-pump. When the valve is open the water runs down into the boiler, but when closed it runs away by an overflow shoot. The foot of the stand-pipe penetrates to nearly the bottom of the boiler, so that steam cannot escape by it, but the water rises in the stand-pipe to a height proportionate to the pressure of the steam, and a most effectual safety-valve is thus provided, which will come into operation in the event of a dangerous pressure being attained. In the stand-pipe a float is placed, which rises and falls as the pressure of the steam varies, and opens or closes the damper leading from the boiler-flue to the chimney. Some stand-pipes are contracted in their diameter below the level at which the damper-float usually operates, and danger has arisen from this cause; for the float has descended into this narrow neck when there was no longer a pressure of steam in the boiler, and by stopping up the passage it has prevented the access of the feed-water. The length of the damper-chain should be so regulated as to obviate accidents of this description.

Ashcroft's *Magnetic Water-Gauge*, for stationary and steam-boat boilers, consists of a movable magnet in the inside of the boiler, which controls a needle on a dial outside of the boiler, the connection between the two being entirely magnetic.

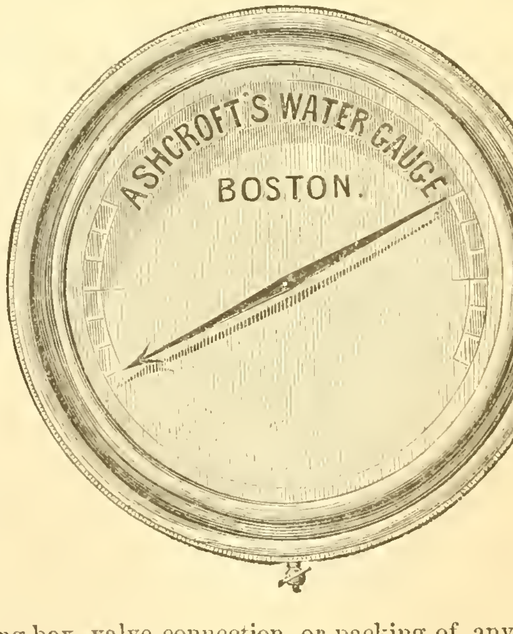
Fig. 426 is a front view of the dial, showing the needle and graduation. Fig. 427 is a sectional view of the gauge.

*A* is a copper ball or float attached to a brass rod, *B*, which passes through a pipe into the chamber of the gauge, on the end of which is affixed a steel magnet, having its positive and negative poles. The rod plays in the pipe with perfect freedom, having no stuffing-box, valve connection, or packing of any kind about it: hence there is no friction. The needle on the dial moves on a polished silver pin, and is controlled by the magnet. It will constantly indicate the level of solid water. Foaming or priming has no effect upon the gauge.

425.



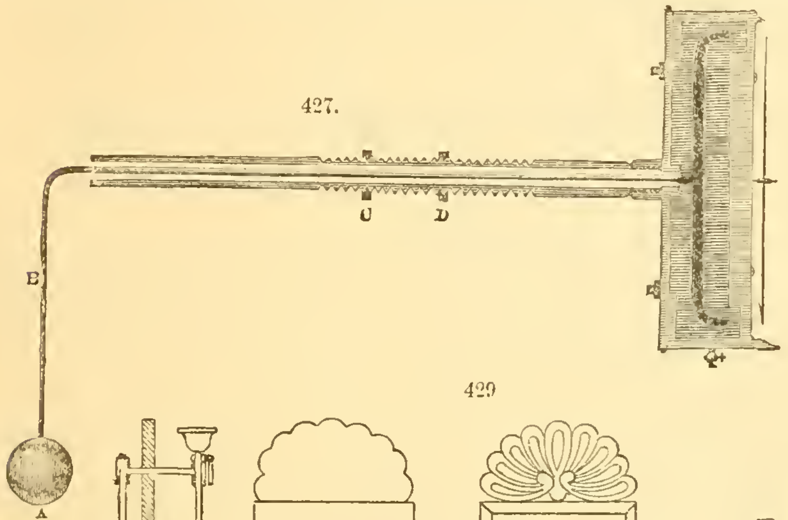
426.



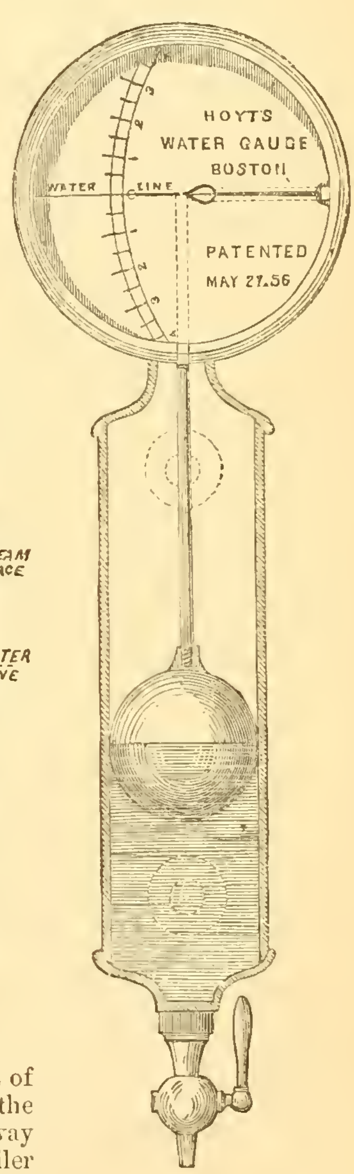

The scale on the dial will indicate a rise or fall of 12 inches of water, each degree measuring 2 inches.

The accompanying engraving (Fig. 428) represents Hoyt's water-gauge, partly in section. It is a simple mechanical invention for telling, at all times, the position of the water in steam-boilers. The dotted circles show the connection with the boiler; the cock at the bottom is a blow-out cock for the prevention of sediment. Its advantages are its durability, simplicity, and its constant and accurate indication of the solid water within the boiler, the foam not being dense enough to move or affect the float, which, being filled with compressed air, is in no danger of loading or collapsing by the pressure upon its surface. The float is also directly connected with the indicating hand, by means of a lever and shaft working in a steam-tight case elevated above the water, so that no sediment can collect about the shaft, to prevent its always working with perfect ease and accuracy. No packing is needed, as the shaft, in passing through the case to connect with the indicator, forms of itself a perfectly steam-tight joint—not creating friction enough to prevent its working perfectly free at all times. It is easily applied to all kinds of steam-boilers, locomotive, stationary, and steamboat.

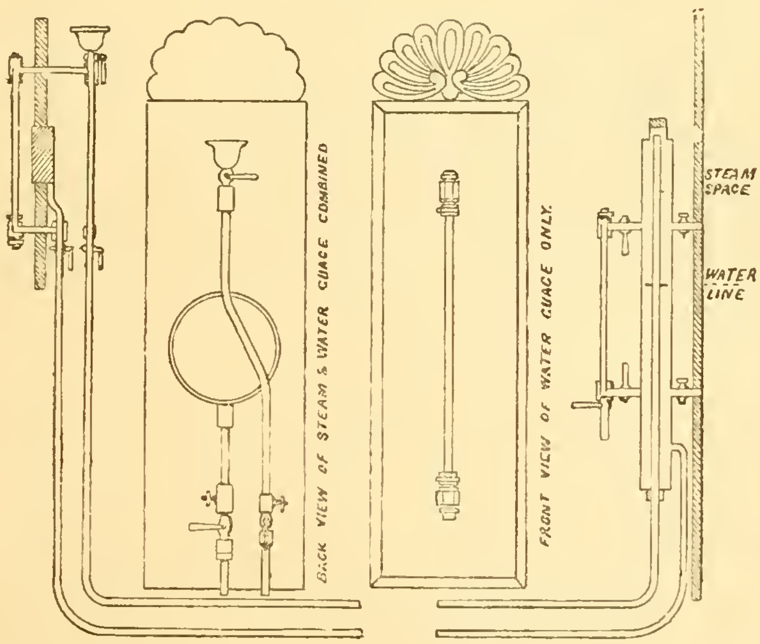
427.




428.




429



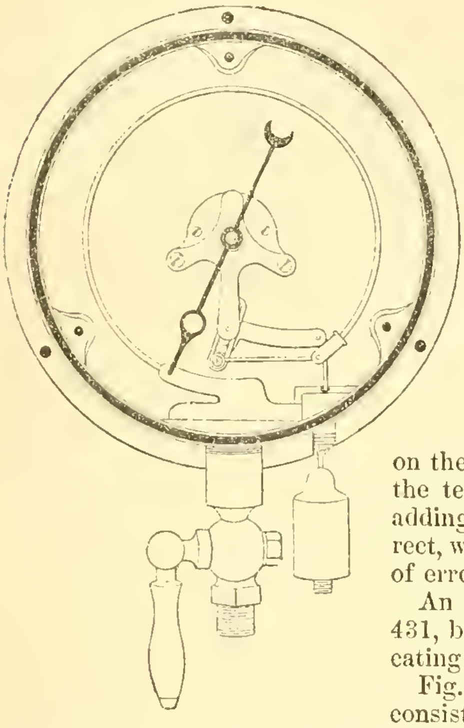

The Nicholas water-gauge, Fig. 429, is designed to show the height of water in a boiler, when located at any level and at any distance from the boiler. An ordinary glass gauge is placed in any desired position away from the boiler, and connected to a cylinder interposed between the boiler and its water-gauge, in the manner shown. The connecting-pipes and detached gauge are filled with water to any convenient height, and some colored fluid is introduced into the space above the water, so that, when the water-level changes in the boiler, it changes to the same extent in the connecting-tubes, and causes a movement of the colored fluid in the glass, thus indicating the amount of change.

*Steam-Gauges.*—The gauges commonly used for indicating the pressure of steam, water, air, and other fluids, may be divided into two classes: gauges in which the pressure is measured by the movement of springs, upon which the pressure acts, and gauges in which the pressure is balanced by a column of heavy liquid, such as mercury. In all forms of steam-gauges, the connecting-pipe is generally bent, so that the part next to the gauge shall always contain water when in use, in order that the mechanism may not be injured by undue heat. Spring-gauges may be classed as those in which the pressure is transmitted by action within the spring, or against the spring through the medium of an elastic diaphragm.

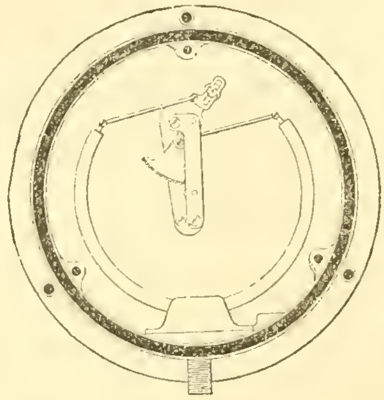
Both varieties are illustrated on page 186. Fig. 430 shows one form of the well-known Bourdon gauge, in which the pressure acts within a coiled and flattened tube. When internal pressure is applied to such a tube, the tendency is to change the flattened section into a circle, and thus to straighten the tube, so that an indicating-hand attached to the end of the tube will be moved along the scale. This

form of gauge is sometimes arranged as shown in the figure, so that its accuracy can be tested at any time by hanging a weight at the point indicated. The dial of the gauge has a working-scale, for reading the indications of the hand when moved by steam-pressure, and a test-scale which is used in connection with the weight. The gauge is tested, with the steam-pressure acting upon it, by hanging

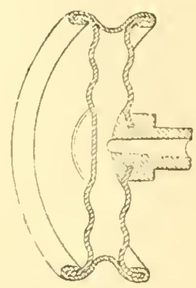
430.



431.



432.



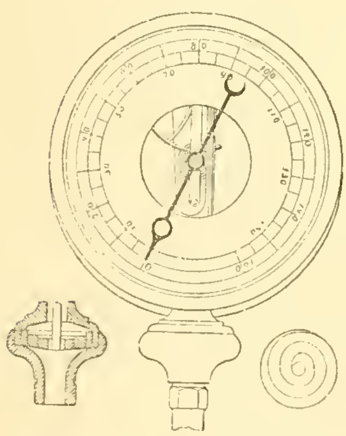
on the weight, when, if the hand falls back to the same figure on the test-scale as that at which it stood on the working-scale before adding the weight, it indicates that the reading of the gauge is correct, while any variation from the former reading shows the amount of error.

An improved form of the Bourdon gauge is illustrated in Fig. 431, both ends of the flattened tube being attached to the indicating mechanism.

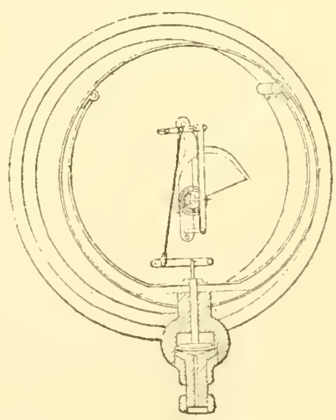
Fig. 432 represents the spring of another variety of gauge, which consists of two corrugated plates connected by a curved band. All the parts of this spring expand when pressure is applied. In the gauges shown in Figs. 433 and 434, the pressure is transmitted to the springs through elastic diaphragms. In Fig. 433 a coiled spring is employed, and in Fig. 434 there is a plunger resting on elastic packing, the movement of this plunger being resisted by a spring within the case, of the form shown.

Spring-gauges are tested either by a mercury column or by hydraulic pressure from a test-pump, to which another gauge, known to be correct, is attached. The square-inch test-valve, Fig. 435, is de-

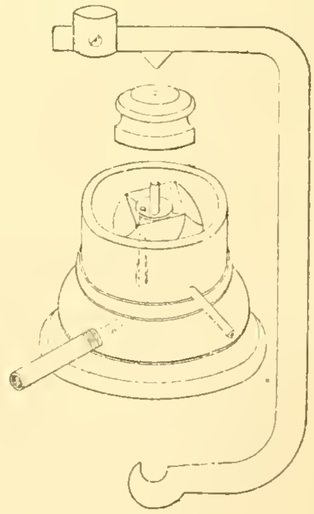
433.



434.



435.

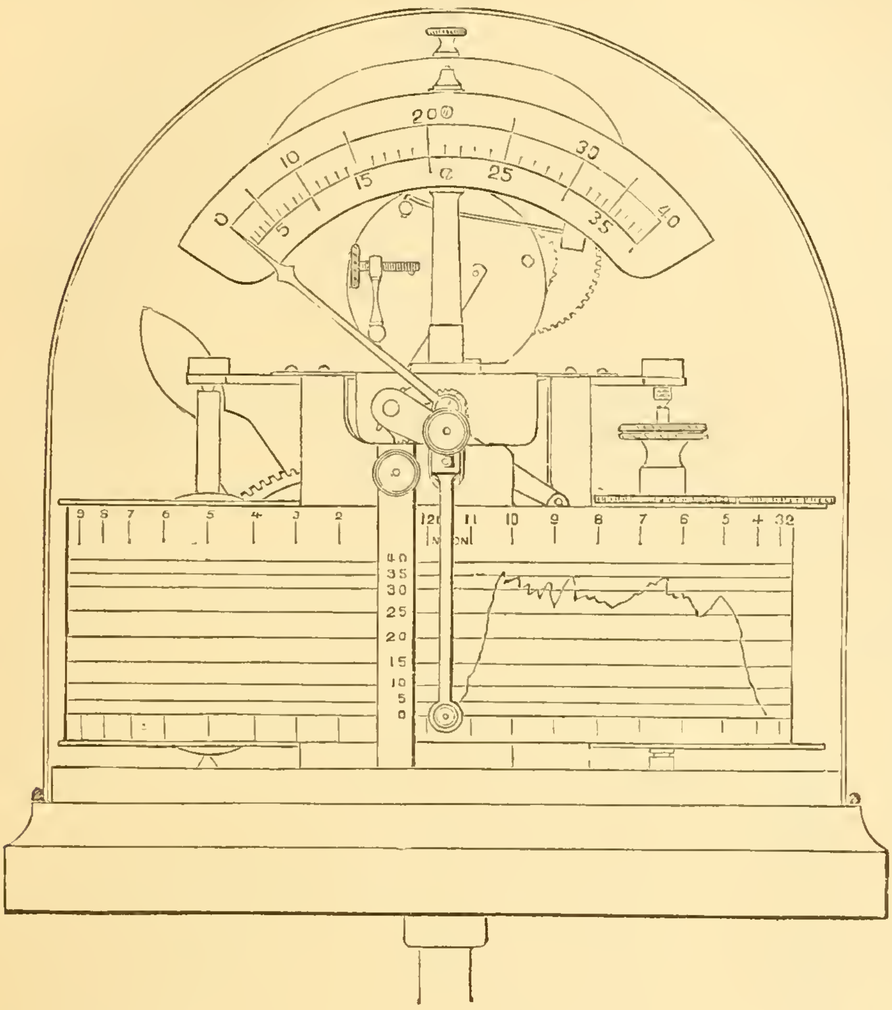


signed to be a cheap and simple substitute for the costly test-gauge. It consists of a valve exactly one square inch in area, a seat which can be connected with the test-pump, and a yoke to which weights can be hung so as to load the valve to any desired extent, so that, when the apparatus is connected to a test-pump, the valve will continue on its seat, until the required pressure per square inch is attained.

Edson's recording steam-gauge, Figs. 436, 437, not only indicates the pressure at every instant, but also makes a record, showing what the pressure was at any particular time, and gives an alarm if the pressure exceeds a prescribed limit. The pressure is indicated by the movement of a spring in the form of a corrugated steel disk, and a pencil attached to the indicating-hand presses against a strip of paper which is made to move uniformly by the action of clock-work. Horizontal lines on the paper form a pressure scale, and vertical divisions a scale of time, as will be evident from an inspection of Figs. 438 and 439, which are reduced copies of two records of pressure for 24 hours each. When the pressure exceeds a certain limit, which can be fixed at pleasure, a bell attached to the gauge commences to ring, and at the same time connection is made with an electric bell situated wherever desired, which continues to ring until the pressure falls. When the gauge is used to obtain the record of pressure during an experiment, as, for instance, the steam-pressure in a boiler-test, or the water-pressure in the trial of a pumping-engine, the paper is made to move at a faster rate

than for ordinary use. It will be seen that this gauge maintains a constant watch on the care and skill of the boiler-attendant, and might be very useful in the case of a disastrous boiler-explosion, where no witnesses are left to tell the pressure at the time of the accident.

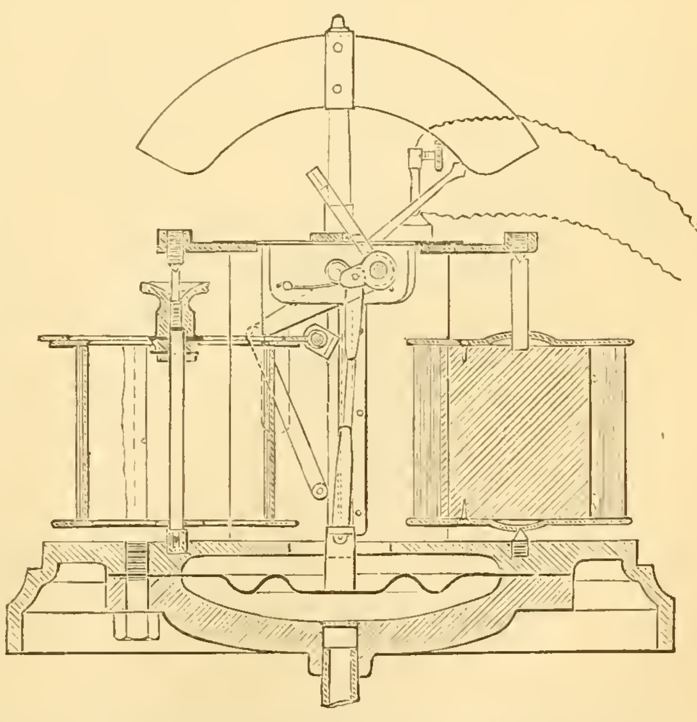
436.




The instrument is covered by a glass dome, which can be secured by means of a strap and lock, preserving the diagram inviolate.

In the other class of pressure-gauges to which reference has been made, the pressure is balanced by a column of heavy liquid, usually mercury. The siphon-gauge, Fig. 440, is the form commonly adopted for measuring low pressures. It is merely a bent tube containing mercury, one end of the tube being connected with the boiler, and the other being open. A light stick is placed on the mercury, which indicates, by rising or falling, how much the column is influenced by the pressure, a change of level of one inch corresponding to a pressure of about one pound per square inch: or there is a float on the mercury connected by a cord with a counter-balance, as shown in the sketch. This form of mercury-gauge cannot be conveniently employed to measure high pressures, on account of the great length of scale and tube required; and there are several arrangements designed to adapt the gauge to general use.

437.

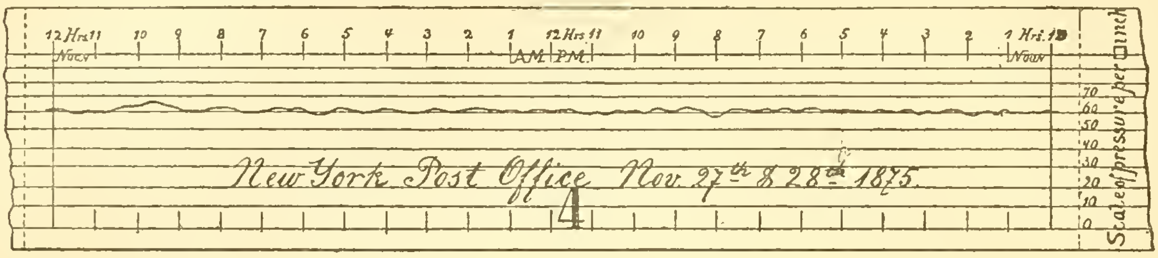


In the ordinary siphon-gauge, the height of column necessary to balance a pressure of one pound per square inch being about two inches, a rise of one inch corresponds to this pressure, since, for a rise in one branch of the tube, there is a corresponding fall in the other. Hence, if the pressure from this gauge were transmitted to a second siphon-gauge, a rise of one inch in the first would produce a rise of only half an inch in the second, one-quarter of an inch in a third siphon, and so on. On this principle a compact mercury-gauge for showing high pressures has been constructed, consisting of a series of siphons filled with mercury, and connected by pipes in which glycerine is used to separate the several mercury columns.

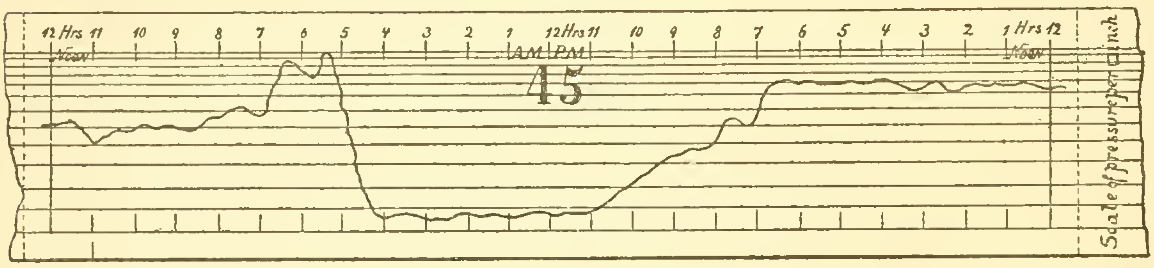
In the manometer steam-gauge a glass tube is inverted in a reservoir of mercury. When the pressure on the surface of the mercury in the reservoir is that of the atmosphere, the mercury will rise in the tube nearly to the level of that surface (but slightly lower, owing to the resistance of the air in the glass tube). As soon, however, as the pressure communicated exceeds that of the atmosphere,

the mercury will be forced up into the tube, and the inclosed air condensed, until its elastic resistance is just equal to the pressure. The height of the mercurial column will of course vary with any variation of pressure, and thereby indicate the degree of pressure at every moment by means of the scale, which is divided, according to Mariotte's law, into atmospheres, pounds, or the like.

438.

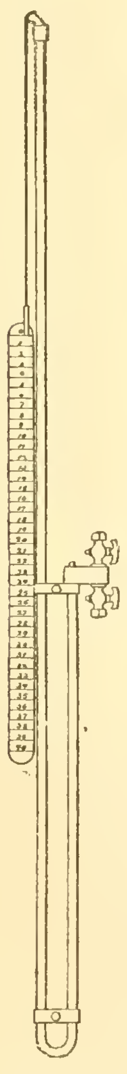



439.




The high degree of pressure to which the last-described form of manometer may be subjected without error from friction or loss of mercury, the permanent elasticity, and the everywhere existing and exactly defined qualities of the material of resistance (atmospheric air, or other fluids of the same nature), its comparatively small dimensions and convenient form, make it a very desirable instrument for measuring the pressure of steam. As usually constructed, however, it has defects, which have prevented its general use as a steam-gauge. Among these defects are the coating and consequent opacity of the glass tube, by the deposition of an oxide of mercury when acted on by the inclosed atmospheric air; the expansion and partial loss of air from within the tube whenever any partial vacuum is produced in the boiler, and so allowing the mercury to rise higher in the tube with the same pressure; its oscillation, especially when there is a varying pressure, as in engines working expansively; the almost constant tendency of the condensed steam to insinuate itself between the mercury and the glass, and to find its way into the tube above the mercury; and the great inequality in the divisions of the scale, arising from the peculiarities of the law that governs the volume of aëriform fluids under pressure.

440.



441.

442.

Some improvements, designed to correct these defects, were patented, some years ago, by Mr. Paul Stillman, of New York.

Fig. 441 is the usual form of the patent manometer for showing a pressure up to eight atmospheres.

Fig. 442 represents the form of one for showing a pressure up to 20 atmospheres.

Fig. 443 is the form used for showing less than 1 atmosphere. The arrangement of the glass tube is quite similar in all the forms usually given to the instrument.

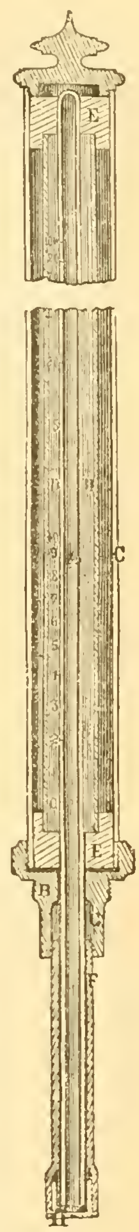
Fig. 444 is a longitudinal section through the centre of the glass tube, in which *A* is the tube; *B* is an iron piece in which the tube is firmly secured by means of the stuffing-box *G*. It is screwed at one end to receive the brass case *C*, and in the middle to confine it in the reservoir of mercury into which the lower end of the tube is to be immersed. *D D* are scales divided into atmospheres, pounds, or inches of pressure, as desired. *E E* are blocks to secure the scales in their proper places. *F* is a gland which protects the lower end of the tube, and compresses the packing in the stuffing-box *G*. *H* is a cap or plug loosely screwed into the gland to facilitate the operation of charging the tube, and also, by admitting the mercury into the tube only through the interstices of the screw, prevent its oscillation, and at the same time allow the orifice to be made the full size of the tube whenever it may be necessary to clean the tube.

In Fig. 441 the reservoir for mercury is a deep cell, with an iron tube communicating from the cock at the bottom to the middle of the chamber above the surface of the mercury. In Fig. 442 it is

divided, the glass tube being inserted into a cell of greater depth, while the reservoir of mercury is in the bulb, to which a sufficient elevation is given to compress the gas within the tube to two or three times the density of the atmosphere, according to the density of the steam of which it is to serve as the gauge. In this, as in the other form, an iron tube communicates the pressure from the cock below to the surface of the mercury in the bulb above. The subdivisions of the scale are by this means much more uniform and distinct than when used at atmospheric pressure only.

443.

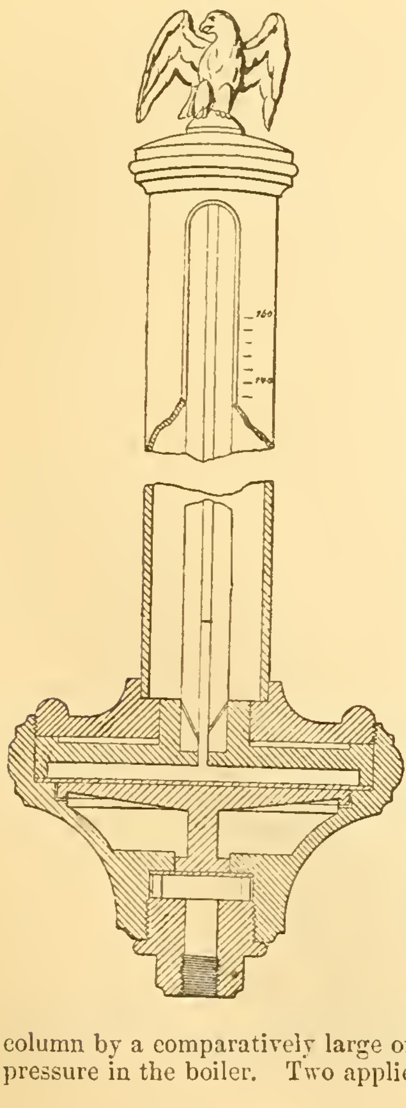
444.



In all cases, the mercury should be seen above the junction of the tube with the tube-holder, so as to indicate the initial pressure, or 0. In Fig. 441 it is brought up by partially exhausting the tube at the time it is erected. In Fig. 442 it is forced up by the superincumbent weight of the mercury in the bulb. The oxidation of the mercury within the tube is prevented in the latter form of the instrument by charging the tube with nitrogen or hydrogen gas; but in the former, on account of the difficulty of preventing the admixture of atmospheric air, while exhausting a portion of the contents of the tube, for the purpose above referred to, atmospheric air only is used, and a drop or two of naphtha, or other fluid answering the end, is introduced within the tube, on the surface of the mercury, to prevent the oxidation.

When designed to show a pressure less than atmospheric, but not less than that shown by two inches of mercury, the tube is to be perfectly filled with mercury, and inverted in the reservoir, and the pressure will be determined by the number of inches sustained above the level of the mercury in the reservoir below; but if it is to be used for a pressure less than the weight of two inches of mercury—that being the distance from the lowest visible part of the glass tube to the surface of the mercury in the reservoir—it will be necessary to use the bulb shown in Fig. 442, but with such an elevation only as will bring the surface of the mercury in it to a height equal to the lowest visible part of the glass tube; or it may be done equally well by using the form shown in Fig. 442, if a scale is properly made for the purpose, and the bulb elevated so as to compress the air so high in the tube as to allow the mercury to have sufficient fall without going out of sight, when the pressure of the atmosphere is removed from the surface of the mercury in the bulb above.

445.



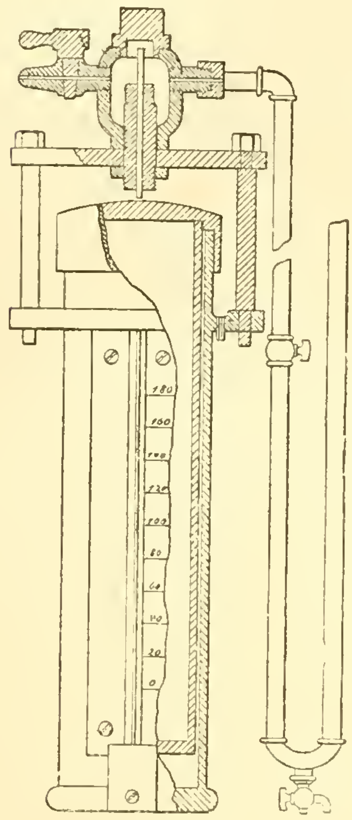
It will be seen that either of these arrangements would resist the tendency of such partial vacuum as is generally formed in steam-boilers, when they are allowed to cool down, from disturbing the quantity of air within the tube of the manometer

If the initial quantity of air or gas in the tube be deranged by a change of temperature, or by any other cause, it becomes necessary to know the extent of the variation occasioned thereby. To ascertain this (if inexpedient to correct it at once), a simple arrangement is adopted, viz.: 1. To remove the pressure by closing the stopcock and opening the small waste-cock between it and the reservoir—this will allow the mercury to fall to a place in which it will be at equilibrium with the atmosphere; 2. To note the point to which it descends. The variation from the original place of 0 will be, in addition to the pounds shown on the scale-plate, such part of the whole as the variation from 0 bears to the whole length of the tube above 0. To determine this proportion, a series of decimals is placed on the scale at fixed distances, and the one of these nearest to where the base of the column of air within the tube rests, is to be used as a multiplier, by which the pressure of steam indicated on the scale is to be multiplied. Their product, less the pounds of variation shown on the scale, will be the true pressure. Thus, for example, if the mercury in the tube falls until the base of the column of air rests at the decimal .96, which would be near to the place due to 1 lb. pressure, and if, on opening the communication to the boiler again, it should rise to 130 lbs., this apparent pressure of 130 lbs. is to be multiplied by .96, and deduct from their product the 1 lb., thus giving as the true pressure 123.8 lbs., showing a variation of 6.2 lbs.

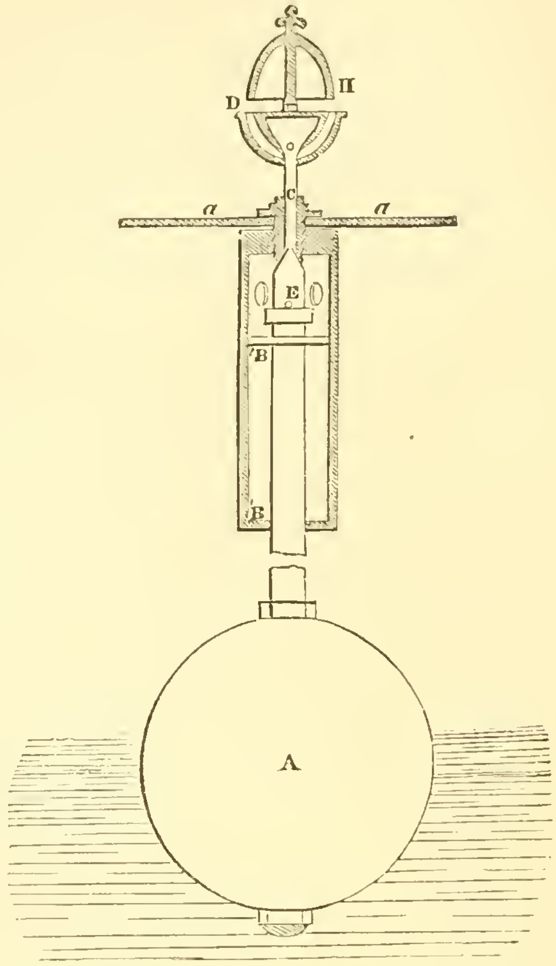
A very convenient and accurate mercury-gauge can be constructed on the differential principle—that is, the pressure can be received on a small surface and transmitted to the mercury column by a comparatively large one, so that a short column of mercury will balance a considerable pressure in the boiler. Two applications of this principle are illustrated.

In Shaw's gauge, Fig. 445, there is a double-headed piston, on the small head of which the steam presses, and the large head transmits this pressure to an open mercury column. The heads are

446.



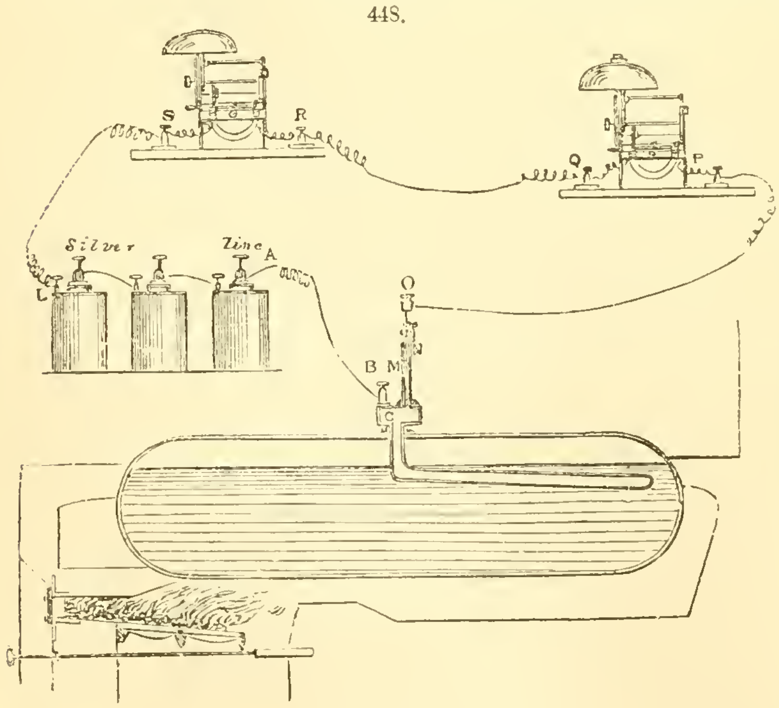
447.




separated from the steam and mercury by rubber diaphragms, so that the piston can be fitted loosely, without any tendency to leak.

The Stiles gauge, Fig. 446, is a model of simplicity and accuracy, no packing being used in its construction. A large iron cylinder fits loosely into another cylinder containing mercury, and a small cylinder, or piston, working freely in its guide, receives the pressure and transmits it to the floating cylinder, causing a rise of mercury corresponding to the relative dimensions of the two pressed surfaces.

448.

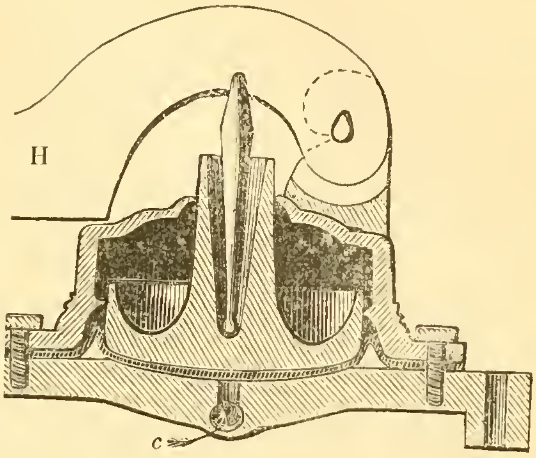



*Low-Water Alarms.*—These attachments are designed to give warning, usually by blowing a whistle when the water-level falls below a certain point. They depend generally for their action either on the motion of a float which opens the whistle-valve when not buoyed up by the water in the boiler, or on the direct pressure of steam, which is only admitted to the whistle-pipe when the water-level is depressed, or on the expansion of some portion of the attachment when exposed to contact with steam instead of water.

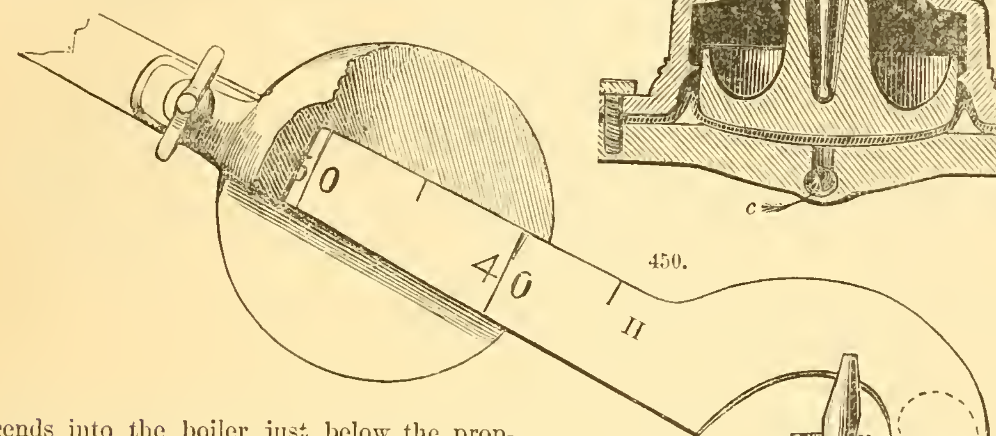
Fig. 447 is a float-alarm. $A$ is a float attached to a stem or rod which passes upward through a tube, $B^1$, and a diaphragm, $B^2$, fixed within that tube, and terminates in a conical top, which fits into the hollow pipe $C$ of the steam-whistle $D$. The lower end of the whistle $D$ is passed through an orifice in the top of the boiler (indicated by the letters $a$ $a$), and screwed into the top of the tube,

which is thus kept steady, if in a vertical position. $E$ is a collar attached to the stem of the float, near the top, which, catching against the plate $B^2$, on the fall of the stem or rod $A$, prevents it from descending farther. When the water falls below the safety-line, and the float along with it, the descent of the stem of the float opens the pipe $C$ of the whistle, and allows the steam to escape, which, impinging against the bell $H$ at top, produces the alarm required.

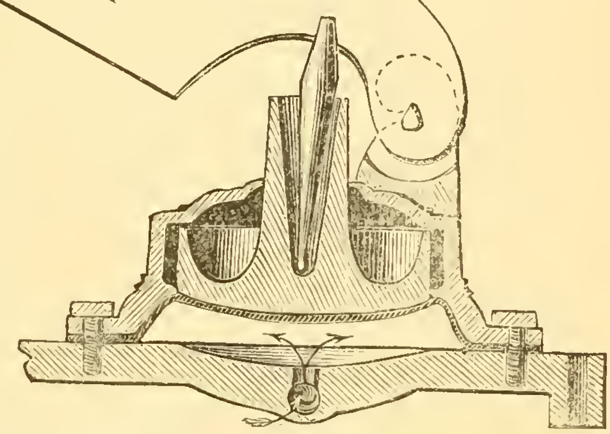
449.




One form of an alarm which acts by expansion is illustrated in Fig. 448, which represents so much of a steam-boiler as is necessary for our description. A tube de-



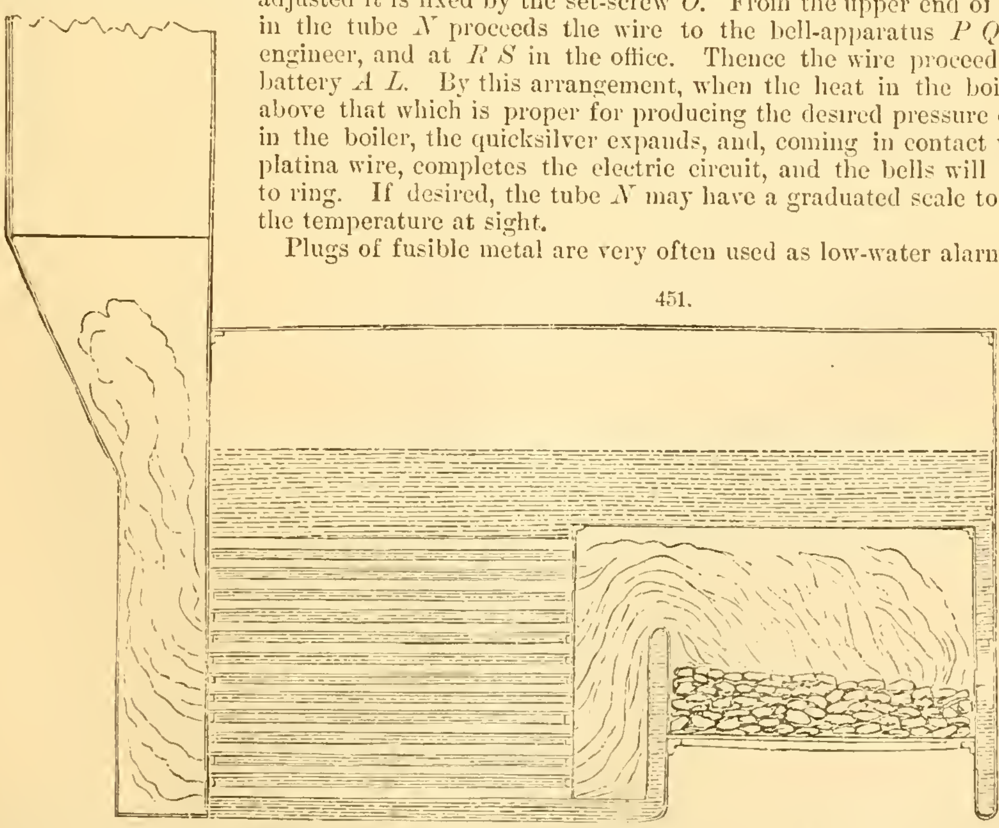
450.



scends into the boiler just below the proper water-line, and is secured to the sides. The branch $C$ is fixed to the upper end, into which two tubes, $B$ and $N$, are fixed. The tubes and the branch $C$ are filled with mercury to a fixed level at the proper temperature of the boiler. In the tube $N$ is a wire set in such a manner that its lower end, which should be of platina, will come just above the quicksilver in the tube when it stands at the height which will be caused by the heat which should produce the pressure of steam desired in the boilers; and at starting, the apparatus is to be adjusted when the steam is at the working-pressure in the boiler; and when the wire is so adjusted it is fixed by the set-screw $O$. From the upper end of the wire in the tube $N$ proceeds the wire to the bell-apparatus $P\ Q$ for the engineer, and at $R\ S$ in the office. Thence the wire proceeds to the battery $A\ L$. By this arrangement, when the heat in the boiler rises above that which is proper for producing the desired pressure of steam in the boiler, the quicksilver expands, and, coming in contact with the platina wire, completes the electric circuit, and the bells will continue to ring. If desired, the tube $N$ may have a graduated scale to indicate the temperature at sight.

Plugs of fusible metal are very often used as low-water alarms, being

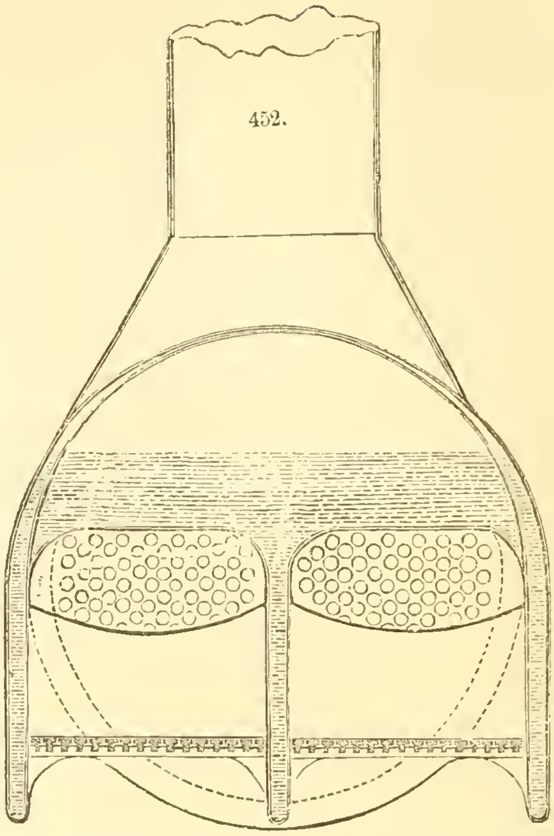
451.



[Figs. 451 and 452 are copper boilers, 8 feet, made by H. R. Dunham & Co., for steamboat Independence.]

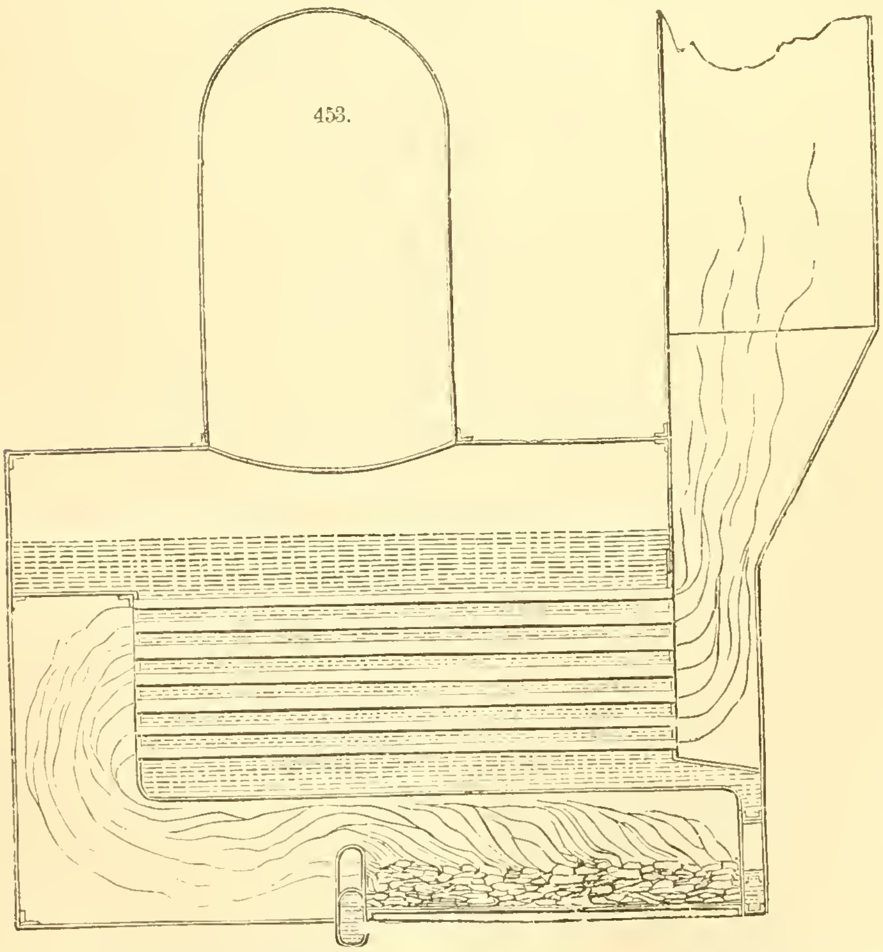
screwed into some portion of the boiler directly over the fire, so that if the plate becomes overheated on account of low water, the plug will melt. No form of boiler-alarm is intended to induce the attendant of a boiler to relax his vigilance, but rather to remind him of his duty. No *mechanical* appliance can entirely take the place of *intelligent* watchfulness.

*Damper-Regulators.*—These attachments are designed to control the draught mechanically, closing the damper when the steam pressure exceeds a given limit, and opening it as the pressure falls. Although there have been modifications of detail since the instrument was first introduced in this country, its essential features are shown in Figs. 449, 450, which illustrate the regulator patented by Patrick Clark, in January, 1854. Both figures are in section. The construction can be readily understood. The steam from the boiler is introduced beneath a vulcanized rubber diaphragm, upon which rests a piston weighted, like a common safety-valve, to its lever *H*, to which a rod is attached, which connects with the damper in the chimney or flue. Fig. 449 shows the position of the diaphragm and piston when the pressure in the boiler is below that required; when the pressure exceeds that which is desired, the diaphragm and piston are forced up, and the damper begins to close, till it attains the position, Fig. 450, when the draught is entirely shut off. The amount of pressure is controlled by the sliding weight or pea on the steelyard arm *H*, as shown in Fig. 450. The diaphragm is composed of a cup or cylinder, and the patentee claims "the combination of a cylindrical diaphragm with a cylinder and piston," by which any desired amount of motion may be given from 1 inch to 10 feet; but for a movement not greater than 1 inch, he observes that a flat disk will answer, provided the cylinder is made as shown in the figures. In some forms of the instrument, recently introduced, corrugated diaphragms are used instead of a piston or plunger.



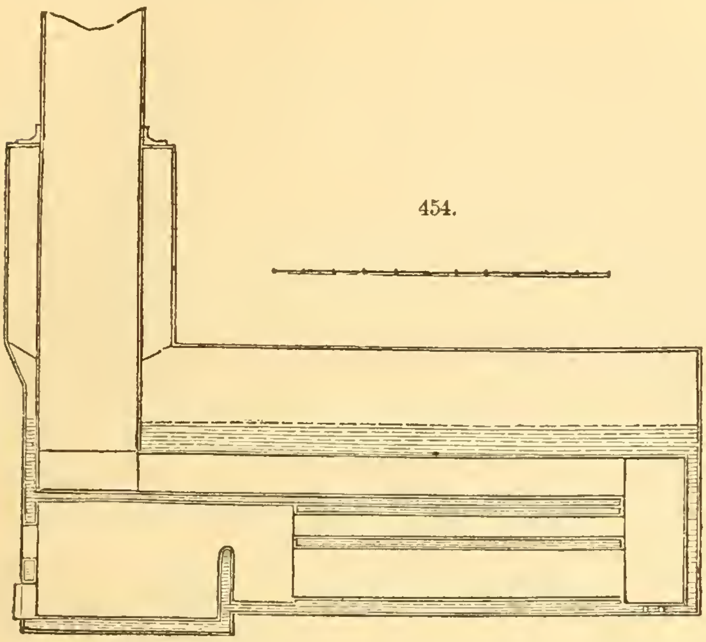

*Marine Boilers.*—The illustrations of boilers used for marine purposes, Figs. 451 to 464, will give a good idea of past and present practice.

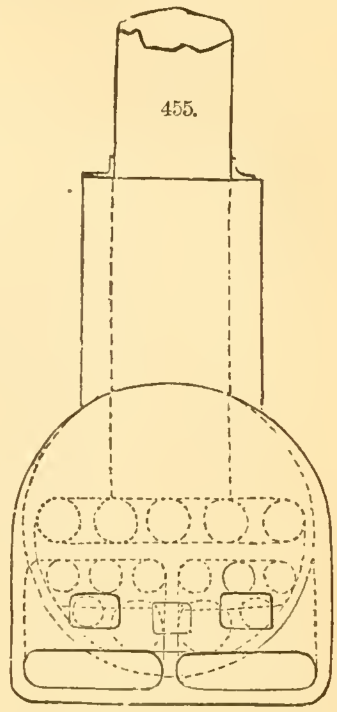
In the year 1837, Robert L. Stevens, Esq., constructed a pair of boilers, of tubular form, for his steamboat Independence, plying between South Amboy and New York, of which Figs. 451 and 452 are correct representations, the form of which was well adapted to the burning of anthracite as fuel, by the assistance of bellows, or what is ordinarily termed the fan. No difficulty was ever found in the accomplishment of the purpose they were intended to effect; and though many improvements have since that time been adopted, they are still working satisfactorily. To Mr. Stevens belongs the credit of first establishing the water-bridge, which serves the purpose of protecting the mouth of the tubes.




[Fig. 453.—The steamboat New York, built by H. R. Dunham & Co., has one copper boiler, one engine, 40-inch cylinder, 7¼ stroke; entire surface, 1,608, viz: Direct or furnace, 133; tubular, 1,475: 1,608. Burns anthracite coal, without a blower, at the rate of half a ton per hour; keeps 12 inches steam, cuts off at half; 250 2⅝-inch tubes.]

Figs. 454 and 455 represent boilers of the Belle, built by T. F. Secor & Co., which had one engine of 50-inch cylinder, 10 feet stroke; 136 cubic feet in cylinder, which gives, in proportion to the boiler, $11\frac{32}{136}$ to 1. Used anthracite, with a blower.




*Fire-Surface in this Boiler.*

| | |
|---|---|
| In the steam chimney | 12.000 |
| " front connection | 85.039 |
| " return flues | 477.062 |
| " back connection | 114.000 |
| " main flues | 621.028 |
| " furnace, bridge-wall, etc | 218.052 |
| Total number of square feet in boiler | 1,527.181 |

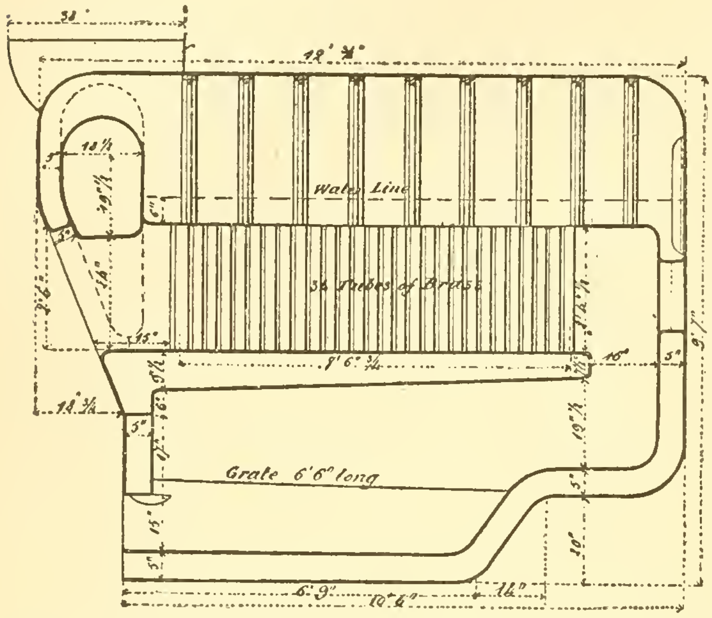
A vertical water-tube boiler patented by D. B. Martin was used almost to the exclusion of every other form in the United States navy for a number of years. It differs from the Earl of Dundonald's boiler in having the tubes above the furnace. One of the most elaborate series of boiler experiments ever made was the trial, in 1865 and 1866, by a board of engineers, of the vertical water-tube and the horizontal fire-tube boilers, both with the proportions considered the best for general practice, and with various modifications. A full summary of these experiments will be found on pages 198 to 202. The boilers with which the experiments were made represented, at that time, the best examples of standard practice, and the proportions of the horizontal fire-tube boiler were essentially the same as at present. The boilers are illustrated in Figs. 456 to 459, and the principal dimensions are as follows:

| | Horizontal Fire-Tube Boiler. | Vertical Water-Tube Boiler. |
|---|---|---|
| Length | 10 ft. 4 in. | 10 ft. 6 in. |
| Width | 7 ft. 5¼ in. | 7 ft. 5½ in. |
| Height | 9 ft. 7 in. | 9 ft. 7 in. |
| Number of furnaces | 2 | 2 |
| Length of each furnace | 6 ft. | 6 ft. 6 in. |
| Width " " | 3 ft. | 3 ft. |
| Total grate-surface | 36 sq. ft. | 39 sq. ft. |
| Number of tubes | 162 | 748 |
| Length of tubes | 7 ft. 3 in. | 2 ft. 4½ in. |
| External diameter of tubes | 2¼ in. | 2 in. |
| Thickness of tubes | 0.109 in. | 0.109 in. |
| Heating-surface: Furnace | 96.57 sq. ft. | 96.76 sq. ft. |
| " " Back-connection | 116.66 " | 73.97 " |
| " " Tube-boxes | ........... | 147.07 " |
| " " Tubes | 701.8 " | 929.8 " |
| " " Smoke-box | 34.9 " | 17.21 " |
| " " Total | 949.93 " | 1264.81 " |
| Air-spaces in grates | 11.23 " | 14.1 " |
| Tube calorimeter | 4.6 " | 5.54 " |
| Cross-section of chimney | 6.78 " | 6.78 " |
| Height of chimney above grate | 60 ft. | 60 ft. |
| Weight of boiler | 39,480 lbs. | 42,088 lbs. |

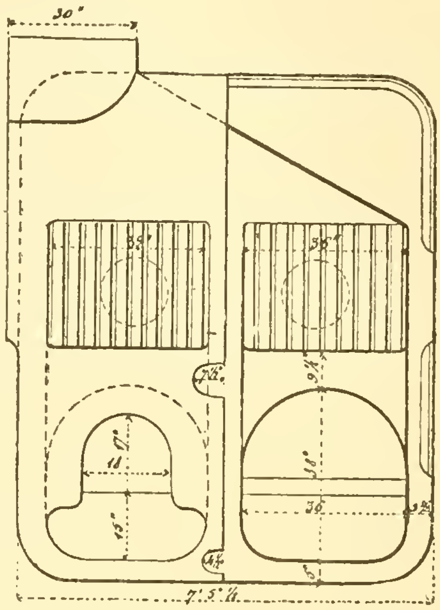
The general result of the experiments was to show that, as the boilers were constructed, the vertical water-tube boiler was the most economical, but as rapid a rate of combustion could not be main-

tained in it as in the other, with natural draught. In varying the proportions, however, it was found that, by removing a sufficient number of the vertical tubes, the water-tube boiler could be made to burn coal at the same rate as the fire-tube boiler, and with about the same economy. This

456.

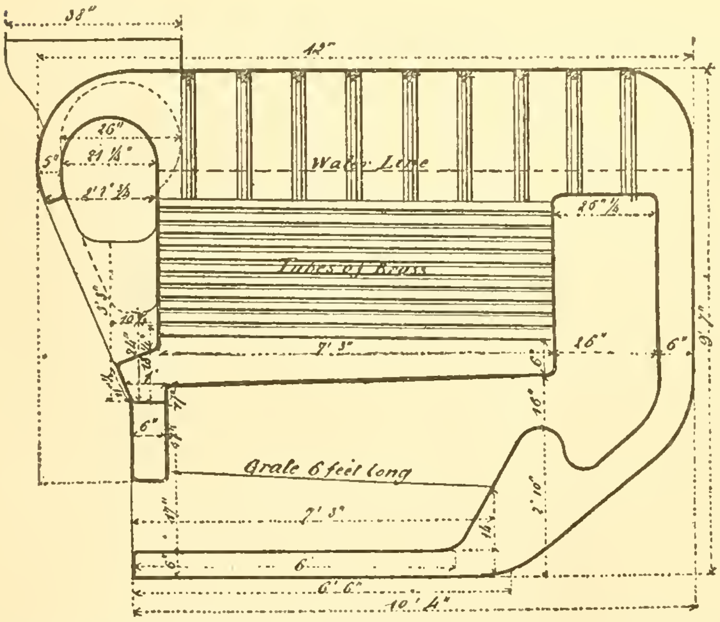



457.

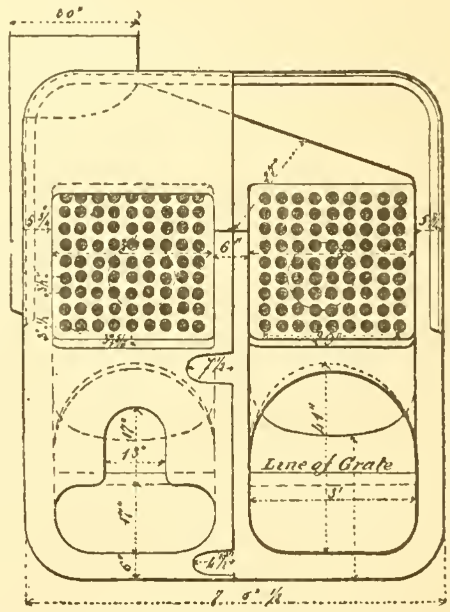


fact does not seem to have been very generally noticed, but it is well illustrated in the boiler designed by Theron Skeel, Fig. 460, which seems to have some important advantages over the ordinary fire-tube boiler. Fig. 462 shows the space at present occupied by the boilers and fire-room of

458.




459.




the P. M. S. S. Colon, and Fig. 461 the space required for Mr. Skeel's water-tube boilers to evaporate the same amount of water as the others. The following table illustrates this point more fully:

*Boilers for Steamship Colon.*

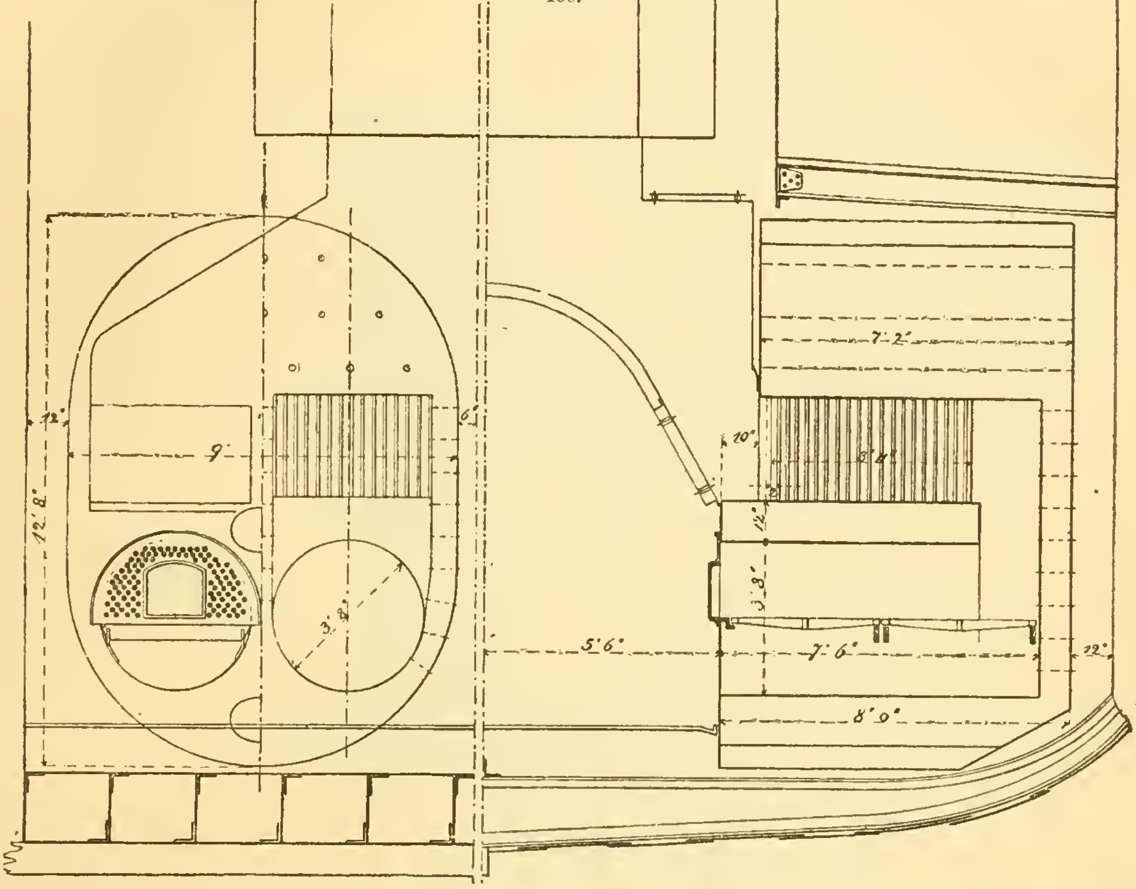
| | Present Boilers. Horizontal Fire-Tube. | Mr. Skeel's Proposed Boilers. Vertical Water-Tube. |
|---|---|---|
| Grate-surface in four boilers | 224 sq. ft. | 224 sq. ft. |
| Heating " " " | 5,480 " | 3,560 " |
| Cross area in flues | 54 " | 34 " |
| Weight of four boilers in tons (2,240 lbs.) | 88 | 44 |
| Cubic feet of space in four boilers and fire-room | 13,500 | 9,120 |
| Pounds of anthracite coal per hour | 3,000 | 3,000 |
| " water evaporated from 100° per hour | 24,000 | 24,000 |

The objections are sometimes made to the vertical water-tube boiler, that the tube-boxes cannot be cleaned quite as readily as the horizontal tubes, and that a leaky tube in the water-tube boiler cannot be stopped as readily as an horizontal fire-tube, since in the former case the water must be

blown from the boiler before the tube can be plugged or expanded. Practically, however, these objections are not very serious.

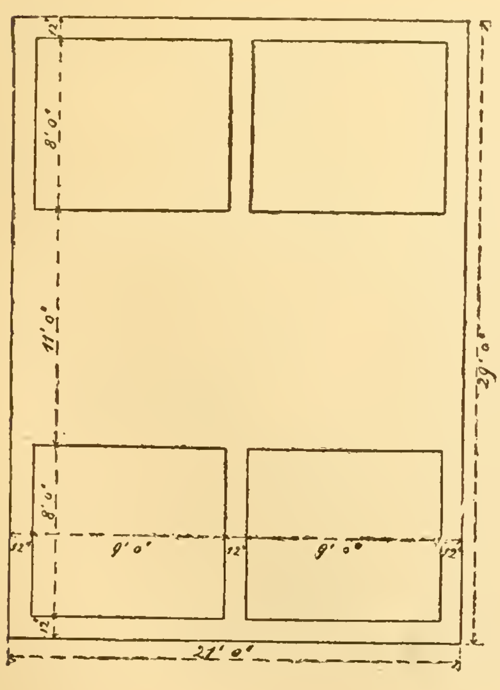
Fig. 464, *A* and *B*, illustrate the modern marine boiler, which is now in general use. It is a

460.

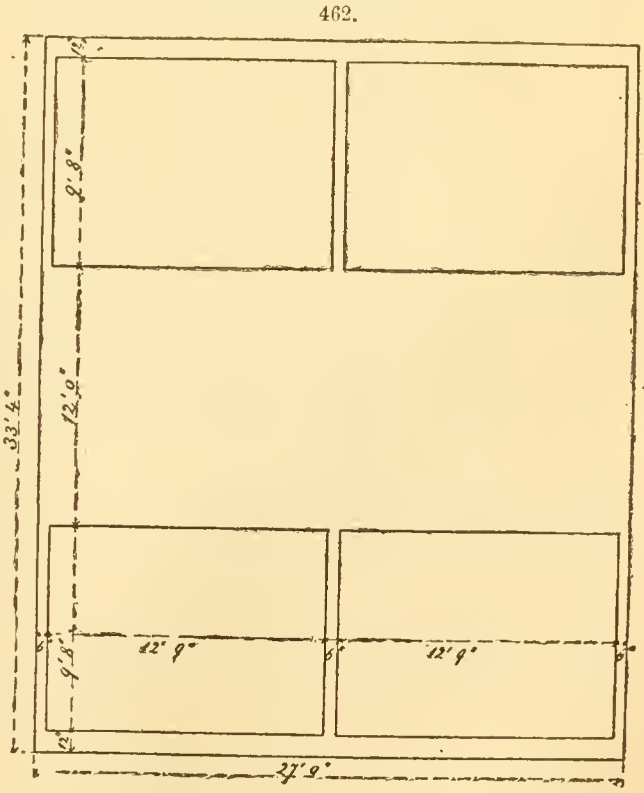



tubular boiler with a cylindrical shell, and cylindrical flues which form the furnaces. In this example the flues are strengthened by ring-joints, as shown. The shells are double-riveted throughout, and the longitudinal seams are made with butt-joints, with covering plates on each side. Some

461.



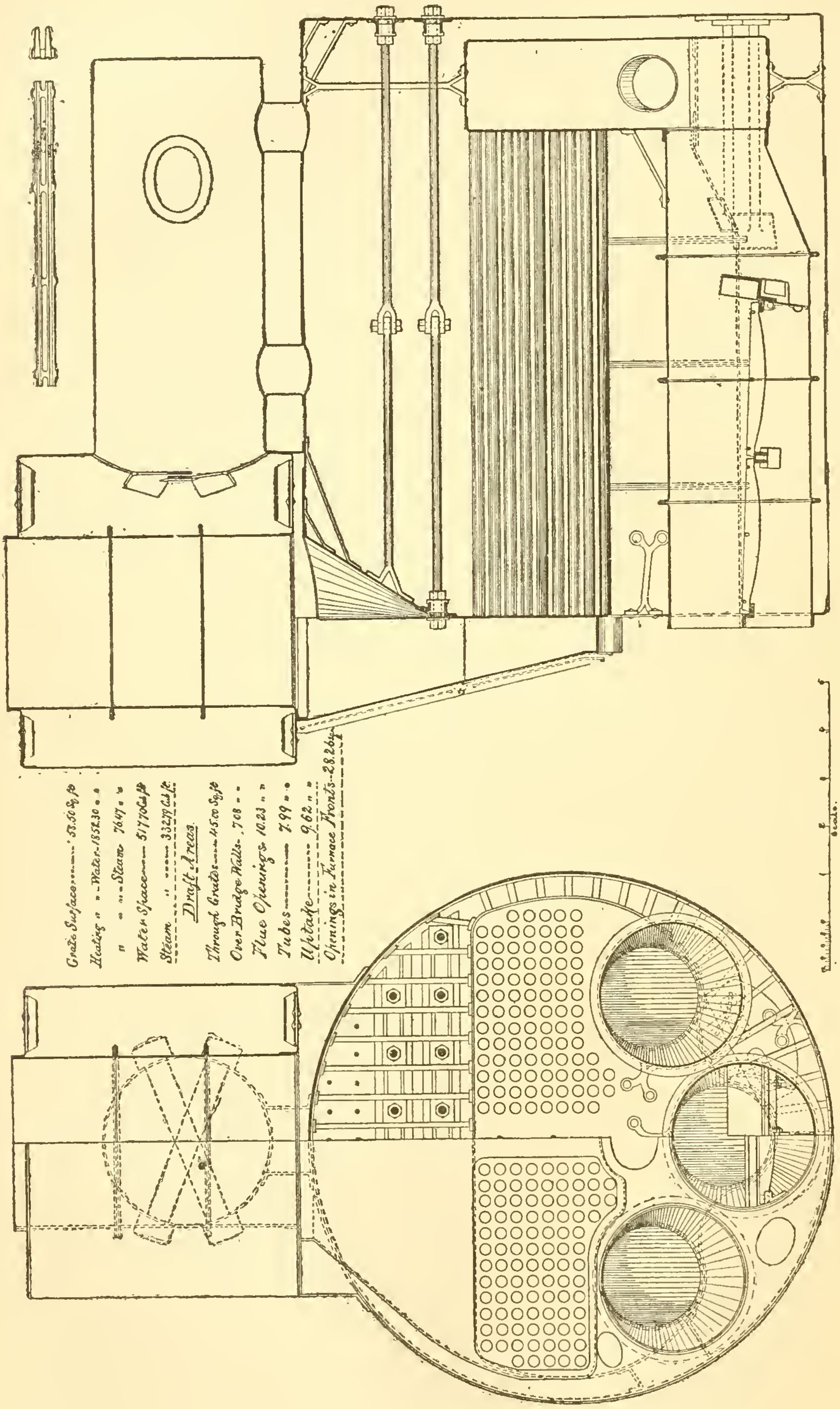

462.




of the tubes are of extra thickness, to take the place of longitudinal braces, being secured with nuts at the ends.

Fig. 463 gives views of a boiler designed by Mr. C. E. Emery, of New York, which is selected as

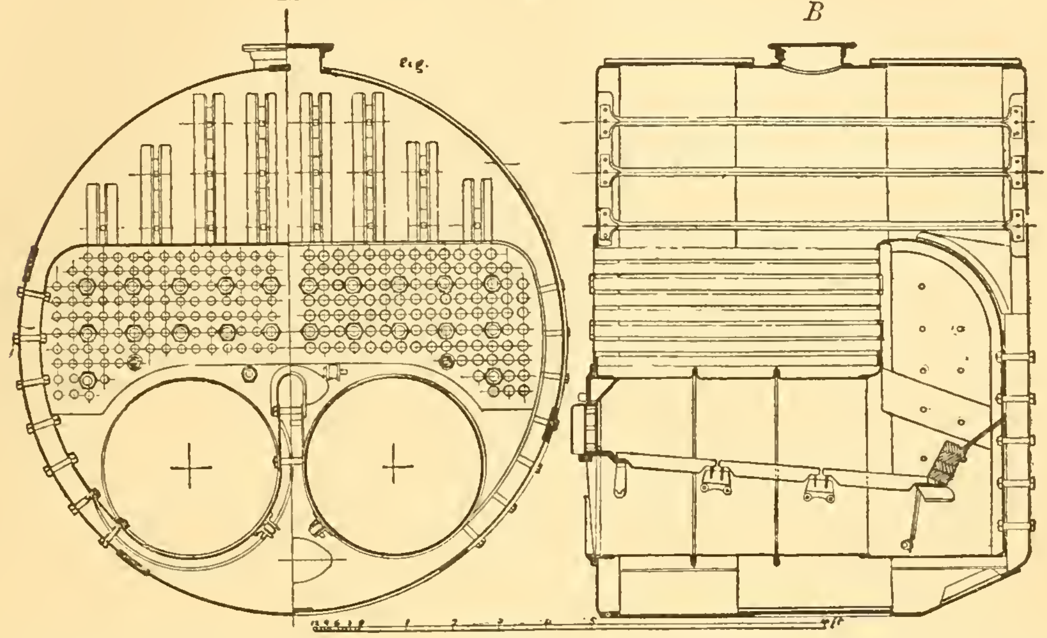
463.




STEAM-BOILER DESIGNED BY C. E. EMERY, C. E., OF NEW YORK.

a good example of modern practice. The principal dimensions will be found on the plate, and the peculiarities of construction are there clearly detailed. The large opening from steam-drum to shell, which ordinarily would be a source of weakness, is strengthened by transverse braces arranged very nearly in the direct lines of the strains, the same being crossed simply to permit the passage of

464.




a man above and below them. The connection from drum to boiler is made through oval openings of man-hole size, which do not materially weaken the main shell. The coning of back ends of furnace-flues gives access from the central man-hole. The main longitudinal braces are screwed at the ends, as shown, and pass between angle-irons, which stiffen the plates. All longitudinal seams and those in flat surfaces are double-riveted, and the furnace-flues are stiffened by flanging ends of sections outward, and riveting flanges together through calking rings.

The sectional boiler, several varieties of which have been illustrated, and which is now successfully used on land, has been tried in ocean-steamers, but so far with but indifferent success, many of the tubes being destroyed in a short time, probably on account of imperfect circulation under the rapid rate of evaporation required. It is not improbable, however, that this difficulty will be overcome. (In the "Transactions of the Institution of Naval Architects," 1876, is a paper containing an account of the experiments that have been made with sectional boilers at sea. This paper may also be found in *Engineering*, xxi., and an abstract of it in Chief-Engineer King's "Report on European Ships of War.")

*Proportions of Boilers.*—The water-heating surface of a boiler is all the surface which has flame or heated gas from the furnace on one side and water on the other. Surface which has flame or hot gas on one side and steam on the other is superheating surface.

The area for the passage of the products of combustion, taken at any section of their course after leaving the furnace and before arriving at the chimney, is called the draught area or calorimeter. Ordinarily, when not otherwise specified, the term refers to the area through or around the tubes of fire and water-tube boilers, and through the flues of flue boilers, although it is equally applicable, as has already been stated, to the area over bridge-wall, or at any other section of the boiler. In some forms of boilers the products of combustion pass directly from the furnace to the chimney—as, for instance, in cylinder, locomotive, and a few sectional boilers; in others, such as boilers with tubes or flues above the furnace, the products of combustion turn once before reaching the chimney; and in examples similar to the drop return flue-boiler, the Lancashire boiler, and other varieties that have been noticed, the products of combustion turn twice in their passage to the chimney. Examples might be given of still a greater number of deflections of the heated gases. It must be evident that the boiler which is so designed that it has the highest furnace and the lowest chimney temperature will evaporate the most water by the consumption of a pound of fuel. The furnace temperature, when the combustion is complete (as is practically the case in well-designed boilers of any type), depends upon the amount of air supplied for combustion, and this is governed principally by the area for the passage of the products of combustion, or the calorimeter. The calorimeter affects the performance of a boiler in another important particular. When it is very large, the hot gases, in passing over the heating surfaces, are not broken up and mingled in such a manner as best to impart their heat to the water, and, by reducing the calorimeter, a more efficient action can often be produced. Until the importance of the calorimeter was first announced by Chief-Engineer B. F. Isherwood, it was commonly supposed that the performance of a boiler was almost entirely dependent upon the ratio of the heating to the grate surface for any given rate of combustion; and this principle is still to be found in many engineering treatises, and is acted upon, to a large extent, in practice.

The best rules that can be given for designing boilers are drawn from experience; and the three tables that follow, containing a summary of some of the most extensive and complete boiler experiments that have ever been made, will be of great value to those who study them carefully.

*Summary of Experiments with Horizontal Fire-Tube Boiler*, 1865, 1866.

| NUMBER FOR REFERENCE. | POUNDS OF COMBUSTIBLE PER HOUR. Total. | Per Square Foot of Grate Surface. | Per Square Foot of Heating Surface. | POUNDS OF WATER EVAPORATED, FROM AND AT 212°. Per Pound of Combustible. | Per Square Foot of Grate Surface, per Hour. | Per Square Foot of Heating Surface, per Hour. | RATIO Of Heating to Grate Surface. | Of Tube Calorimeter to Grate Surface. | Per Cent. of Refuse. | Draught. | Per Cent. of Evaporation for Draught. | REMARKS. | NUMBER FOR REFERENCE. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 699 | 19.43 | .736 | 9.55 | 224.4 | 8.5 | 26.4 | .128 | 17.4 | Natural. | ..... | ........ | 1 |
| 2 | 711 | 19.75 | .748 | 9.43 | 232.9 | 8.82 | " | " | 20. | " | ..... | ........ | 2 |
| 3 | 704 | 19.54 | .746 | 9.52 | 185.8 | 7.04 | " | " | 21.3 | " | ..... | ........ | 3 |
| 4 | 718 | 18.77 | .716 | 9.55 | 179.3 | 6.79 | " | " | 23. | " | ..... | ........ | 4 |
| 5 | 473 | 13.13 | .497 | 11.5 | 150.7 | 5.71 | " | " | 22.8 | " | ..... | ........ | 5 |
| 6 | 608 | 16.9 | .64 | 10.71 | 180.8 | 6.85 | " | " | 23.2 | " | ..... | ........ | 6 |
| 7 | 282 | 7.84 | .297 | 12.45 | 98. | 3.71 | " | " | 23.7 | " | ..... | ........ | 7 |
| 8 | 535 | 17.82 | .562 | 10.79 | 192.2 | 6.00 | 31.7 | .153 | 21.7 | " | ..... | G. S. reduced to 30. | 8 |
| 9 | 260 | 8.65 | .273 | 12.2 | 105.5 | 3.33 | " | " | 18.9 | " | ..... | " " 30. | 9 |
| 10 | 424 | 17.68 | .448 | 11.52 | 203.6 | 5.15 | 39.5 | .192 | 22. | " | ..... | " " 24. | 10 |
| 11 | 209 | 8.71 | .221 | 11.65 | 101.9 | 2.58 | " | " | 16.4 | " | ..... | " " 24. | 11 |
| 12 | 344 | 19.1 | .362 | 11.52 | 219.7 | 4.16 | 52.8 | .256 | 22.8 | " | ..... | " " 18. | 12 |
| 13 | 152 | 8.43 | .16 | 12.29 | 103.7 | 1.96 | " | " | 20.3 | " | ..... | " " 18. | 13 |
| 14 | 257 | 19.02 | .27 | 11.27 | 214.7 | 3.05 | 70.4 | .341 | 20.4 | " | ..... | " " 13.5. | 14 |
| 15 | 109 | 8.08 | .115 | 12.53 | 101. | 1.43 | " | " | 23.3 | " | ..... | " " 13.5. | 15 |
| 16 | 256 | 7.12 | .27 | 12.71 | 90.4 | 3.43 | 26.4 | .128 | 19.6 | " | ..... | ........ | 16 |
| 17 | 645 | 17.92 | .679 | 9.99 | 178.8 | 6.77 | " | " | 16.1 | " | ..... | ........ | 17 |
| 18 | 135 | 3.75 | .142 | 13.08 | 48.8 | 1.85 | " | " | 13.5 | " | ..... | ........ | 18 |
| 19 | 601 | 16.69 | .632 | 9.96 | 166.3 | 6.31 | " | " | 18.6 | " | ..... | ........ | 19 |
| 20 | 437 | 12.15 | .46 | 11.05 | 134.3 | 5.09 | " | " | 16.7 | " | ..... | ........ | 20 |
| 21 | 635 | 17.64 | .668 | 10.45 | 184.8 | 7.01 | " | " | 17.6 | " | ..... | ........ | 21 |
| 22 | 565 | 15.68 | .594 | 10.6 | 166.4 | 6.31 | " | " | 19.4 | " | ..... | ........ | 22 |
| 23 | 438 | 15.2 | .461 | 11.52 | 174.8 | 5.3 | 33. | .16 | 20.9 | " | ..... | G. S. reduced to 28.8. | 23 |
| 24 | 400 | 18.51 | .421 | 11.62 | 214.6 | 4.88 | 44. | .213 | 22.5 | " | ..... | " " 21.6. | 24 |
| 25 | 423 | 14.6 | .111 | 11.59 | 169.4 | 5.16 | 32.8 | .159 | 20.2 | " | ..... | " " 29. | 25 |
| 26 | 663 | 18.43 | .698 | 10.44 | 191.4 | 7.25 | 26.4 | .128 | 17. | " | ..... | ........ | 26 |
| 27 | 733 | 20.35 | .771 | 7.51 | 153.2 | 5.81 | " | " | 18.1 | " | ..... | ........ | 27 |
| 28 | 668 | 18.56 | .703 | 9.47 | 176.1 | 6.67 | " | " | 15.7 | " | ..... | ........ | 28 |
| 29 | 772 | 21.43 | .812 | 7.41 | 158.6 | 6.01 | " | " | 18.2 | " | ..... | ........ | 29 |
| 30 | 671 | 18.64 | .706 | 9.75 | 181.4 | 6.87 | " | " | 16.9 | " | ..... | ........ | 30 |
| 31 | 482 | 21.92 | .128 | 11.20 | 245.3 | 5.68 | 43.2 | .209 | 16.3 | " | ..... | G. S. reduced to 22. | 31 |
| 32 | 669 | 18.58 | .704 | 10.78 | 199.8 | 7.57 | 26.4 | .116 | 16.2 | " | ..... | Ferrules in 4 upper rows of tubes. | 32 |
| 33 | 665 | 18.49 | .701 | 10.78 | 199.8 | 7.57 | " | .102 | 16.3 | " | ..... | " all tubes | 33 |
| 34 | 671 | 18.64 | .706 | 10.91 | 202.7 | 7.68 | " | .095 | 16.4 | " | ..... | " " " | 34 |
| 35 | 597 | 16.59 | .694 | 11.42 | 189.2 | 7.92 | 23.9 | .114 | 19.4 | " | ..... | Upper row of tubes plugged. | 35 |
| 36 | 600 | 16.67 | .779 | 11.19 | 185.9 | 8.69 | 21.4 | .1 | 19.5 | " | ..... | More tubes plugged. | 36 |
| 37 | 628 | 17.44 | .661 | 11.26 | 196.6 | 7.45 | 26.4 | .128 | 22.2 | " | ..... | ........ | 37 |

*Summary of Experiments with Horizontal Fire-Tube Boiler*—(Continued).

| Number for Reference. | Pounds of Combustible per Hour. Total. | Per Square Foot of Grate Surface. | Per Square Foot of Heating Surface. | Pounds of Water Evaporated, from and at 212°. Per Pound of Combustible. | Per Square Foot of Grate Surface, per Hour. | Per Square Foot of Heating Surface, per Hour. | Ratio. Of Heating to Grate Surface. | Of Tube Calorimeter to Grate Surface. | Per Cent. of Refuse. | Draught. | Per Cent of Evaporation for Draught. | Remarks. | Number for Reference. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 38 | 669 | 18.59 | .704 | 10.68 | 198. | 7.5 | 26.4 | .128 | 17.2 | Natural. | ..... | Flat deflecting plate in back connection ...... | 38 |
| 39 | 616 | 17.12 | .619 | 10.54 | 179.6 | 6.8 | " | " | 20.7 | " | ..... | Concave " " " " ...... | 39 |
| 40 | 675 | 18.74 | .71 | 10.56 | 198.2 | 7.51 | " | " | 17.5 | " | ..... | Two " plates " " ...... | 40 |
| 41 | 805 | 22.37 | .847 | 10. | 223.7 | 8.47 | " | " | 16.3 | Jet. | 4.01 | ...... | 41 |
| 42 | 780 | 21.67 | .821 | 9.88 | 214.4 | 8.12 | " | " | 18.5 | Fan. | 3.82 | ...... | 42 |
| 43 | 783 | 21.76 | .824 | 9.25 | 201.4 | 7.63 | " | " | 17.7 | " | 4.49 | ...... | 43 |
| 44 | 778 | 21.62 | .819 | 11.06 | 239.8 | 9.08 | " | " | 20.8 | " | 9.38 | ...... | 44 |
| 45 | 797 | 22.15 | .839 | 11.36 | 251.9 | 9.54 | " | " | 18.9 | " | 9.25 | ...... | 45 |
| 40 | 546 | 15.16 | .634 | 12.05 | 182.7 | 7.64 | 23.9 | .114 | 20.8 | Natural. | ..... | Upper row of tubes plugged ...... | 46 |
| 47 | 536 | 14.88 | .564 | 12.75 | 189.2 | 7.17 | 26.4 | .128 | 21.5 | " | ..... | ...... | 47 |
| 48 | 549 | 15.24 | .577 | 12.17 | 185.4 | 7.02 | " | " | 20.3 | " | ..... | ...... | 48 |
| 49 | 780 | 21.66 | .821 | 11.18 | 241.9 | 9.16 | " | " | 24.2 | Fan. | 11.2 | ...... | 49 |
| 50 | 513 | 19. | .54 | 12.92 | 245.1 | 6.96 | 35.2 | .148 | 22.4 | " | 10.1 | G. S. reduced to 27. Ferrules in 4 upper rows of tubes. | 50 |
| 51 | 659 | 18.3 | .847 | 11.23 | 205. | 7.76 | 26.4 | .128 | 18.2 | Jet. | 5.1 | ...... | 51 |
| 52 | 671 | 18.63 | 3.15 | 5.86 | 109. | 18.5 | 5.9 | .067 | 19.3 | Natural. | ..... | Tubes closed ...... | 52 |
| 53 | 259 | 7.88 | 1.33 | 8.24 | 64.9 | 11. | " | " | 17. | " | ..... | " " ...... | 53 |
| 54 | 494 | 13.73 | 2.32 | 6.89 | 94.4 | 15.9 | " | " | 17.9 | " | ..... | " " ...... | 54 |
| 55 | 556 | 15.45 | .585 | 11.47 | 177.1 | 6.71 | 26.4 | .087 | 18.9 | " | ..... | Ferrules in tubes ...... | 55 |
| 56 | 558 | 15.49 | .587 | 11.37 | 175.6 | 6.65 | " | .111 | 18.6 | " | ..... | " " ...... | 56 |
| 57 | 505 | 14.03 | .635 | 11.58 | 162.4 | 7.35 | 22.1 | .099 | 20.2 | " | ..... | Two upper rows of tubes plugged ...... | 57 |
| 58 | 482 | 13.4 | .673 | 11.67 | 156.8 | 7.88 | 19.9 | .085 | 18.9 | " | ..... | Three " " " " ...... | 58 |
| 59 | 417 | 11.57 | .654 | 12.77 | 147.2 | 8.32 | 17.7 | .071 | 21. | " | ..... | Four " " " " ...... | 59 |
| 60 | 403 | 11.21 | .723 | 11.81 | 132.2 | 8.53 | 15.5 | .057 | 18.7 | " | ..... | Five " " " " ...... | 60 |
| 61 | 310 | 8.62 | .643 | 12.28 | 106. | 7.91 | 13.4 | .043 | 21.4 | " | ..... | Six " " " " ...... | 61 |
| 62 | 210 | 5.82 | .52 | 12.38 | 84.6 | 7.55 | 11.2 | .028 | 19.6 | " | ..... | Seven " " " " ...... | 62 |
| 63 | 88 | 2.43 | .267 | 13.6 | 33.1 | 3.63 | 9.1 | .014 | 21.3 | " | ..... | Eight " " " " ...... | 63 |
| 64 | 507 | 14.09 | .534 | 11.72 | 165. | 6.26 | 26.4 | .083 | 19.5 | " | ..... | Ferrules in tubes ...... | 64 |
| 65 | 546 | 15.18 | .575 | 11.55 | 174.8 | 6.62 | " | " | 18.9 | " | ..... | " " ...... | 65 |
| 66 | 519 | 14.42 | .546 | 11.75 | 168.5 | 6.38 | " | " | 13. | " | ..... | " " ...... | 66 |
| 67 | 356 | 11.42 | .282 | 11.6 | 132.2 | 3.27 | 40.4 | .142 | 15.4 | " | ..... | G. S. reduced to 31.25 ...... | 67 |
| 68 | 571 | 18.28 | .452 | 11.01 | 201.3 | 4.98 | " | " | 15. | " | ..... | " " " ...... | 68 |
| 69 | 453 | 14.51 | .359 | 11.47 | 166.8 | 4.13 | " | " | 13.9 | " | ..... | " " " ...... | 69 |
| 70 | 157 | 5.03 | .125 | 12.63 | 63.4 | 1.57 | " | " | 17.6 | " | ..... | " " " ...... | 70 |
| 71 | 123 | 3.42 | .13 | 11.25 | 38.3 | 1.45 | 26.4 | .1 | 15. | " | ..... | Ferrules in tubes ...... | 71 |
| 72 | 244 | 6.79 | .257 | 11.96 | 81.5 | 3.09 | " | " | 13.6 | " | ..... | " " ...... | 72 |
| 73 | 370 | 10.26 | .389 | 11.81 | 121.5 | 4.6 | " | " | 13.6 | " | ..... | " " ...... | 73 |

*Summary of Experiments with Vertical Water-Tube Boiler*, 1865, 1866.

| Number for Reference. | Pounds of Combustible per Hour. Total. | Per Square Foot of Grate Surface. | Per Square Foot of Heating Surface. | Pounds of Water Evaporated, from and at 212°. Per Pound of Combustible. | Per Square Foot of Grate Surface, per Hour. | Per Square Foot of Heating Surface, per Hour. | Ratio. Of Heating to Grate Surface. | Of Tube Calorimeter to Grate Surface. | Per Cent. of Refuse. | Draught. | Per Cent. of Evaporation for Draught. | Remarks. | Number for Reference. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 500 | 12.81 | .395 | 10.83 | 175. | 5.41 | 32.4 | .142 | 21.2 | Natural. | ..... | ..... | 1 |
| 2 | 480 | 12.31 | .38 | 12.13 | 148.8 | 4.59 | " | " | 21.7 | " | ..... | ..... | 2 |
| 3 | 494 | 12.66 | .391 | 11.88 | 150.6 | 4.65 | " | " | 23.6 | " | ..... | ..... | 3 |
| 4 | 489 | 12.55 | .387 | 11.79 | 147.9 | 4.57 | " | " | 23.5 | " | ..... | ..... | 4 |
| 5 | 462 | 11.84 | .365 | 11.99 | 141.6 | 4.37 | " | " | 23.9 | " | ..... | ..... | 5 |
| 6 | 414 | 11.51 | .355 | 12.29 | 123.1 | 3.8 | 35.1 | .154 | 23.5 | " | ..... | G. S. reduced to 36 | 6 |
| 7 | 285 | 7.3 | .225 | 13.27 | 97.1 | 2.99 | 32.4 | .142 | 22.9 | " | ..... | ..... | 7 |
| 8 | 348 | 11.61 | .275 | 13.01 | 150.8 | 3.57 | 42.2 | .185 | 24.3 | " | ..... | G. S. reduced to 30. | 8 |
| 9 | 258 | 8.6 | .204 | 13.33 | 114.4 | 2.71 | " | " | 19.4 | " | ..... | " " 30. | 9 |
| 10 | 292 | 12.17 | .231 | 13.55 | 164.7 | 3.13 | 52.7 | .231 | 23.9 | " | ..... | " " 21. | 10 |
| 11 | 207 | 8.64 | .164 | 12.7 | 109.7 | 2.08 | " | " | 17. | " | ..... | " " 24. | 11 |
| 12 | 228 | 12.66 | .180 | 13.28 | 168.9 | 2.4 | 70.3 | .308 | 25.3 | " | ..... | " " 18. | 12 |
| 13 | 149 | 8.27 | .118 | 13.44 | 110.8 | 1.58 | " | " | 21.7 | " | ..... | " " 18. | 13 |
| 14 | 162 | 12.02 | .128 | 12.81 | 153.6 | 1.64 | 93.7 | .411 | 23.1 | " | ..... | " " 13.5 | 14 |
| 15 | 108 | 8. | .085 | 13.79 | 110.4 | 1.18 | " | " | 24.2 | " | ..... | " " 13.5 | 15 |
| 16 | 254 | 6.51 | .201 | 13.55 | 87.9 | 2.71 | 32.4 | .142 | 20.4 | " | ..... | ..... | 16 |
| 17 | 633 | 16.23 | .501 | 10.54 | 170.1 | 5.25 | " | " | 17.4 | Jet. | 10.18 | ..... | 17 |
| 18 | 134 | 3.44 | .106 | 13.7 | 47.1 | 1.45 | " | " | 15.3 | Natural. | ..... | ..... | 18 |
| 19 | 370 | 10.27 | .296 | 12.7 | 130.8 | 3.73 | 35.1 | .154 | 21.3 | " | ..... | G. S. reduced to 36. | 19 |
| 20 | 428 | 11.88 | .339 | 12.16 | 145.2 | 4.13 | " | " | 18.4 | " | ..... | " " 36. | 20 |
| 21 | 626 | 16.05 | .495 | 11.02 | 176.6 | 5.45 | 32.4 | .142 | 18.8 | Jet. | 5.37 | ..... | 21 |
| 22 | 545 | 15.15 | .468 | 11. | 166.7 | 4.75 | 35.1 | .154 | 22. | " | 7.17 | G. S. reduced to 36. | 22 |
| 23 | 299 | 9.59 | .237 | 13.02 | 124.7 | 3.08 | 40.5 | .178 | 24.5 | Natural. | ..... | " " 31.2 | 23 |
| 24 | 285 | 12.19 | .225 | 13.25 | 161. | 2.98 | 54.1 | .237 | 26. | " | ..... | " " 23.4 | 24 |
| 25 | 327 | 10.42 | .091 | 13.12 | 136.2 | 3.38 | 40.3 | .177 | 23.3 | " | ..... | " " 31.4 | 25 |
| 26 | 661 | 18.36 | .523 | 10.64 | 195. | 5.56 | 35.1 | .154 | 16.7 | Jet. | 8.63 | " " 36. | 26 |
| 27 | 450 | 12.49 | .385 | 12.76 | 160. | 4.94 | " | " | 19.9 | " | 7.74 | " " 36. | 27 |
| 28 | 530 | 14.71 | .451 | 13.02 | 199.8 | 6.17 | " | " | 19.8 | " | 4.99 | " " 36. | 28 |
| 29 | 497 | 13.81 | .426 | 12.88 | 178. | 5.07 | " | " | 19.5 | " | 4.29 | " " 36. | 29 |
| 30 | 531 | 14.75 | .455 | 12.94 | 190.9 | 5.89 | " | " | 19.5 | " | 3.49 | " " 36. | 30 |
| 31 | 577 | 14.78 | .456 | 11.82 | 174.6 | 5.39 | 32.4 | .142 | 18.3 | " | 3.54 | ..... | 31 |
| 32 | 626 | 17.39 | .496 | 11.62 | 201.8 | 5.75 | 35.1 | .154 | 16.7 | " | 6.09 | G. S. reduced to 36. | 32 |
| 33 | 620 | 15.89 | .491 | 12.1 | 192.4 | 5.94 | 32.4 | .142 | 16.8 | " | 5.85 | ..... | 33 |
| 34 | 627 | 16.07 | .496 | 11.97 | 191.6 | 5.91 | " | " | 16.9 | " | 4.69 | ..... | 34 |
| 35 | 591 | 16.42 | .468 | 12.3 | 201.7 | 5.75 | 35.1 | .154 | 17.3 | " | 4.93 | G. S. reduced to 36. | 35 |
| 36 | 521 | 14.47 | .412 | 12. | 174. | 4.96 | " | " | 19.7 | " | 7.93 | " " 36. | 36 |

*Summary of Experiments with Vertical Water-Tube Boiler*, 1865, 1866—(Continued).

| NUMBER FOR REFERENCE. | POUNDS OF COMBUSTIBLE PER HOUR. | | | POUNDS OF WATER EVAPORATED, FROM AND AT 212°. | | | RATIO | | Per Cent. of Refuse. | Draught. | Per Cent. of Evaporation for Draught. | REMARKS. | NUMBER FOR REFERENCE. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Total. | Per Square Foot of Grate Surface. | Per Square Foot of Heating Surface. | Per Pound of Combustible. | Per Square Foot of Grate Surface, per Hour. | Per Square Foot of Heating Surface, per Hour. | Of Heating to Grate Surface. | Of Tube Calorimeter to Grate Surface. | | | | | |
| 37 | 515 | 15.14 | .431 | 12.81 | 193.3 | 5.5 | 35.1 | .154 | 20.8 | Jet. | 5.95 | G. S. reduced to 36. | 37 |
| 38 | 587 | 16.31 | .465 | 12.57 | 205.4 | 5.85 | " | " | 16.4 | " | 4.34 | " " 36. | 38 |
| 39 | 496 | 12.71 | .392 | 13.11 | 166.6 | 4.45 | 32.4 | .142 | 15.9 | " | 3.77 | | 39 |
| 40 | 379 | 15.92 | .081 | 12.74 | 201.9 | 3.8 | 53.1 | .233 | 15.9 | Natural. | ..... | G. S. reduced to 23.8. | 40 |
| 41 | 675 | 17.3 | .534 | 11.32 | 195.5 | 6.03 | 32.4 | .129 | 15.3 | Jet. | 5.66 | Calorimeter reduced by plates. | 41 |
| 42 | 662 | 16.97 | .524 | 11.54 | 195.5 | 6.04 | " | .114 | 16.5 | " | 7.39 | " " rods in tube spaces. | 42 |
| 43 | 646 | 16.56 | .511 | 11.85 | 195.9 | 6.04 | " | .142 | 16.9 | " | 5.86 | Chimney reduced to 4.14. | 43 |
| 44 | 667 | 17.1 | .528 | 11.39 | 194.9 | 6.02 | " | .114 | 16.6 | " | 5.25 | Calorimeter reduced by rods in tube spaces. | 44 |
| 45 | 558 | 14.32 | .408 | 12.01 | 171.6 | 5.3 | " | .125 | 18.8 | Natural. | ..... | " " " " | 45 |
| 46 | 505 | 12.94 | .369 | 12.39 | 160. | 4.94 | " | .111 | 17.6 | " | ..... | " " " " | 46 |
| 47 | 486 | 12.45 | .355 | 12.61 | 157.5 | 4.86 | " | .1 | 18.4 | " | ..... | " " " " | 47 |
| 48 | 599 | 15.37 | .781 | 11.22 | 175.5 | 8.76 | 19.7 | .126 | 18.8 | Jet. | 5.43 | Bars in upper tube spaces. | 48 |
| 49 | 596 | 15.29 | .899 | 11.01 | 168.3 | 9.9 | 17. | .11 | 19.1 | Jet. | 5.55 | Bars in upper tube spaces. | 49 |
| 50 | 369 | 9.47 | .292 | 13.3 | 126. | 3.89 | 32.4 | .1 | 18.6 | Natural. | ..... | " between tubes. | 50 |
| 51 | 449 | 11.51 | .355 | 13.15 | 151.8 | 4.69 | " | " | 22.2 | " | ..... | " " | 51 |
| 52 | 218 | 6.36 | .196 | 13.4 | 85.2 | 2.63 | " | " | 17.4 | " | ..... | " " " | 52 |
| 53 | 637 | 17.69 | .504 | 11.23 | 198.2 | 5.65 | 35.1 | .154 | 20.1 | Jet. | 5.99 | " " " G. S. reduced to 36. | 53 |
| 54 | 666 | 17.08 | .527 | 11.15 | 189.8 | 5.86 | 32.4 | .142 | 17. | " | 4.3 | | 54 |
| 55 | 602 | 15.44 | .477 | 11.7 | 180.2 | 5.56 | " | " | 22.5 | " | 5.95 | | 55 |
| 56 | 671 | 17.22 | .532 | 11.03 | 189.2 | 5.84 | " | " | 17.4 | " | 4.9 | | 56 |
| 57 | 657 | 16.83 | .519 | 11.76 | 198.2 | 6.12 | " | " | 18.2 | " | 4.59 | | 57 |
| 58 | 782 | 20.06 | .619 | 9.8 | 197. | 6.08 | " | " | 18.2 | Fan. | 3.98 | | 58 |
| 59 | 779 | 21.65 | .617 | 9.23 | 200.8 | 5.7 | 35.1 | .154 | 17.8 | " | 4.56 | G. S. reduced to 36. | 59 |
| 60 | 1,050 | 26.93 | .831 | 7.17 | 192.9 | 5.95 | 32.4 | .142 | 16.8 | " | 6.37 | | 60 |
| 61 | 167 | 4.27 | .132 | 14.37 | 61.5 | 1.9 | " | .1 | 12.1 | Natural. | ..... | Bars between tubes. | 61 |
| 62 | 679 | 17.4 | .537 | 12.51 | 217.5 | 6.71 | " | .142 | 16.7 | Fan. | 6.65 | | 62 |
| 63 | 760 | 19.49 | .602 | 12.47 | 242.5 | 7.48 | " | " | 17.4 | " | 7.33 | | 63 |
| 64 | 736 | 18.87 | .582 | 13.32 | 230.6 | 7.12 | " | .1 | 17.3 | " | 8.19 | Bars between tubes. | 64 |
| 65 | 337 | 8.65 | .258 | 14.06 | 117.7 | 3.63 | " | .111 | 23.8 | Natural. | ..... | " " " | 65 |
| 66 | 550 | 15.29 | .436 | 11.33 | 172.9 | 4.93 | 35.1 | .154 | 19.6 | Jet. | 5.80 | G. S. reduced to 36. | 66 |
| 67 | 304 | 7.78 | .24 | 14.86 | 115.9 | 3.58 | 32.4 | .1 | 20.8 | Natural. | ..... | Bars between tubes. | 67 |
| 68 | 545 | 13.97 | .431 | 13.39 | 187.6 | 5.79 | " | .111 | 20.9 | Jet. | 8.81 | " " " | 68 |
| 69 | 324 | 8.31 | .257 | 13.75 | 114.7 | 3.54 | " | .1 | 16.1 | Natural. | ..... | " " " | 69 |
| 70 | 701 | 17.98 | .555 | 12.14 | 217.8 | 6.72 | " | .142 | 20.9 | Fan. | 12.08 | | 70 |
| 71 | 668 | 17.12 | .529 | 12.98 | 222.3 | 6.86 | " | .1 | 19.1 | " | 8.06 | Bars between tubes. | 71 |
| 72 | 488 | 12.51 | .385 | 12.95 | 148.4 | 4.59 | " | .142 | 18.7 | Jet. | 4.7 | | 72 |

*Summary of Experiments with Vertical Water-Tube Boiler*, 1865, 1866—(Continued).

| Number for Reference. | Pounds of Combustible per Hour. Total. | Per Square Foot of Grate Surface. | Per Square Foot of Heating Surface. | Pounds of Water Evaporated, from and at 212°. Per Pound of Combustible. | Per Square Foot of Grate Surface, per Hour. | Per Square Foot of Heating Surface, per Hour. | Ratio. Of Heating to Grate Surface. | Of Tube Calorimeter to Grate Surface. | Per Cent. of Refuse. | Draught. | Per Cent. of Evaporation for Draught. | Remarks. | Number for Reference. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 73 | 492 | 12.61 | .389 | 13.1 | 165.1 | 5.1 | 32.4 | .142 | 20.2 | Jet. | 7.36 | ........ | 73 |
| 74 | 661 | 16.95 | 3.66 | 6.13 | 104.2 | 22.5 | 4.6 | .068 | 19.5 | Natural. | ..... | Tube spaces closed | 74 |
| 75 | 261 | 6.7 | 1.45 | 8.14 | 54.5 | 11.8 | “ | “ | 16.3 | “ | ..... | “ “ “ | 75 |
| 76 | 495 | 12.7 | 2.74 | 7.03 | 89.3 | 19. | “ | “ | 17.8 | “ | ..... | “ “ “ | 76 |
| 77 | 683 | 17.5 | .51 | 12.75 | 204.8 | 6.32 | 32.4 | .1 | 19.1 | Fan. | 8.05 | Plates in tube spaces. Chimney reduced to 3.9 | 77 |
| 78 | 665 | 17.05 | .526 | 12.43 | 194.9 | 6.02 | “ | “ | 18.3 | “ | 7.97 | “ “ “ “ “ “ | 78 |
| 79 | 246 | 13.64 | .194 | 12.66 | 162.7 | 2.31 | 70.3 | .111 | 18. | Jet. | 10.07 | G. S. reduced to 18. Calorimeter reduced | 79 |
| 80 | 570 | 14.62 | .451 | 12.19 | 178.2 | 5.53 | 32.4 | .1 | 18.3 | “ | 4.65 | Calorimeter reduced | 80 |
| 81 | 180 | 9.96 | .142 | 13.31 | 132.5 | 1.88 | 70.3 | .111 | 19.5 | Natural. | ..... | G. S. reduced to 18. Calorimeter reduced | 81 |
| 82 | 103 | 5.94 | .084 | 13.44 | 79.6 | 1.13 | “ | “ | 14.9 | “ | ..... | “ “ “ “ “ | 82 |
| 83 | 495 | 12.68 | .391 | 12.09 | 152.5 | 4.71 | 32.4 | .142 | 16.4 | “ | ..... | Deflecting plates in tube box | 83 |
| 84 | 400 | 10.26 | .317 | 13.16 | 134.6 | 4.16 | “ | “ | 14. | “ | ..... | “ “ “ | 84 |
| 85 | 403 | 10.32 | .819 | 13.11 | 134.9 | 4.16 | “ | “ | 13.6 | “ | ..... | “ “ “ | 85 |
| 86 | 572 | 14.66 | .453 | 12.59 | 184. | 5.68 | “ | “ | 16.1 | Jet. | 5.14 | “ “ “ | 86 |
| 87 | 390 | 9.99 | .308 | 13.23 | 131.9 | 4.07 | “ | “ | 16.2 | Natural. | ..... | “ “ “ | 87 |
| 88 | 779 | 19.96 | .616 | 12.03 | 240. | 7.41 | “ | “ | 16.1 | Fan. | 7.97 | “ “ “ | 88 |
| 89 | 393 | 10.08 | .323 | 13.2 | 132. | 4.23 | 31.2 | “ | 15.2 | Natural. | ..... | 3 rows of tubes removed | 89 |
| 90 | 457 | 11.72 | .376 | 12.55 | 147.4 | 4.73 | “ | “ | 17.2 | “ | ..... | “ “ “ “ | 90 |
| 91 | 677 | 17.37 | .557 | 12.16 | 211.1 | 6.76 | “ | .1 | 17.5 | Fan. | 7.77 | “ “ “ “ Calorimeter reduced | 91 |
| 92 | 392 | 10.05 | .345 | 12.89 | 129. | 4.43 | 29.1 | .142 | 15.5 | Natural. | ..... | 5 “ “ “ | 92 |
| 93 | 491 | 12.58 | .432 | 12.63 | 158.8 | 5.46 | “ | “ | 17.9 | “ | ..... | “ “ “ “ | 93 |
| 94 | 401 | 10.28 | .381 | 12.63 | 129.5 | 4.8 | 27. | “ | 13.8 | “ | ..... | 9 “ “ “ | 94 |
| 95 | 509 | 13.06 | .484 | 12.05 | 157.2 | 5.82 | “ | “ | 16.6 | “ | ..... | “ “ “ “ | 95 |
| 96 | 395 | 10.14 | .407 | 12.5 | 126.3 | 5.07 | 24.9 | “ | 14.6 | “ | ..... | 12 “ “ “ | 96 |
| 97 | 568 | 14.55 | .585 | 11.77 | 171.1 | 6.87 | “ | “ | 16.4 | “ | ..... | “ “ “ “ | 97 |
| 98 | 402 | 10.32 | .452 | 12.08 | 124.6 | 5.47 | 22.8 | “ | 14.2 | “ | ..... | 15 “ “ “ | 98 |
| 99 | 543 | 13.93 | .611 | 11.64 | 162.6 | 7.13 | “ | “ | 16.5 | “ | ..... | “ “ “ “ | 90 |
| 100 | 404 | 10.37 | .501 | 12.19 | 124.4 | 6.01 | 20.7 | “ | 13.7 | “ | ..... | 18 “ “ “ | 100 |
| 101 | 620 | 15.89 | .767 | 11.2 | 177. | 8.55 | “ | “ | 18.5 | “ | ..... | “ “ “ “ | 101 |
| 102 | 396 | 10.15 | .51 | 11.64 | 118.3 | 6.29 | 18.8 | “ | 15.8 | “ | ..... | 21 “ “ “ | 102 |
| 103 | 636 | 16.31 | .867 | 10.69 | 174.4 | 9.28 | “ | “ | 16.5 | “ | ..... | “ “ “ “ | 103 |
| 104 | 394 | 10.1 | .612 | 11.41 | 115.1 | 6.98 | 16.5 | “ | 16. | “ | ..... | 24 “ “ “ | 104 |

*Summary of Experiments with Boilers of Various Forms.*

| Number for Reference. | Pounds of Combustible per Hour. Total. | Per Square Foot of Grate Surface. | Per Square Foot of Heating Surface. | Pounds of Water Evaporated, from and at 212°. Per Pound of Combustible. | Per Square Foot of Grate Surface, per Hour. | Per Square Foot of Heating Surface, per Hour. | Ratio of Heating to Grate Surface. | Draught Area to Grate Surface. | Per Cent. of Refuse. | Remarks. | | Number for Reference. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | | | |
| I.—Horizontal Fire-Tube Boilers, with the Tubes returned above the Furnace, internally fired. | | | | | | | | | | | | |
| 1 | 51 | 4.74 | .341 | 9.43 | 44.7 | 3.22 | 13.9 | .092 | 14.9 | | | 1 |
| 2 | 101 | 9.38 | .674 | 9.08 | 85.2 | 6.12 | " | " | 14.7 | | | 2 |
| 3 | 146 | 13.49 | .969 | 8.45 | 114. | 8.2 | " | " | 18.6 | | | 3 |
| 4 | 196 | 18.18 | 1.306 | 8.21 | 149.2 | 10.72 | " | " | 17.7 | | | 4 |
| 5 | 241 | 22.34 | 1.605 | 7.96 | 178. | 12.86 | " | " | 24.3 | | | 5 |
| 6 | 139 | 12.89 | 1.113 | 8.25 | 116.3 | 9.18 | 11.6 | .069 | 22.1 | Lower row of tubes plugged | | 6 |
| 7 | 143 | 13.29 | 1.436 | 8.88 | 118. | 12.75 | 9.3 | .046 | 20. | Two lower rows of tubes plugged | | 7 |
| 8 | 133 | 12.32 | 1.781 | 9.07 | 111.7 | 16.15 | 6.9 | .023 | 24.9 | Three " " " " | | 8 |
| 9 | 105 | 12.18 | .706 | 9.24 | 112.4 | 6.46 | 17.2 | .115 | 19.6 | Grate reduced to 8.64 | | 9 |
| 10 | 75 | 11.51 | .505 | 9.29 | 103.7 | 4.61 | 22.8 | .153 | 22.9 | " " 6.48 | | 10 |
| 11 | 52 | 12.13 | .356 | 9.82 | 113.8 | 3.42 | 34. | .229 | 21.4 | " " 4.32 | Experimental Boiler, U. S. Navy-Yard, Brooklyn. | 11 |
| 12 | 147 | 17.04 | .988 | 8.46 | 144. | 8.28 | 17.2 | .115 | 17.8 | " " 8.64 | | 12 |
| 13 | 139 | 21.5 | .941 | 8.2 | 171. | 7.6 | 22.8 | .153 | 21.6 | " " 6.48 | | 13 |
| 14 | 90 | 20.85 | .613 | 8.29 | 165.1 | 4.97 | 34. | .229 | 24.4 | " " 4.32 | | 14 |
| 15 | 124 | 11.5 | .993 | 8.53 | 98.2 | 8.47 | 11.6 | .069 | 16.4 | Lower row of tubes plugged | | 15 |
| 16 | 101 | 9.83 | 1.009 | 9.08 | 84.7 | 9.16 | 9.3 | .046 | 15.4 | Two lower rows of tubes plugged | | 16 |
| 17 | 68 | 6.31 | .912 | 11.16 | 70.4 | 10.04 | 6.9 | .023 | 15.6 | Three " " " " | | 17 |
| 18 | 144 | 13.34 | .958 | 8.7 | 116. | 8.34 | 13.9 | .068 | 19.3 | Ferrules in tubes | | 18 |
| 19 | 144 | 13.29 | .955 | 8.69 | 115.4 | 8.3 | " | .043 | 20. | " " | | 19 |
| 20 | 49 | 4.49 | .323 | 11.23 | 50.4 | 3.62 | " | .019 | 22.4 | " " | | 20 |
| 21 | 150 | 13.85 | .995 | 8.54 | 118.3 | 8.5 | " | .092 | 16.4 | | | 21 |
| 22 | 143 | 13.21 | 3.135 | 6.42 | 84.7 | 20.11 | 4.2 | .067 | 20.3 | All tubes plugged | | 22 |
| 23 | 147 | 13.62 | 3.232 | 6.43 | 87.6 | 20.81 | " | .047 | 17.9 | " " | | 23 |
| 24 | 93 | 8.57 | 2.035 | 7.9 | 67.8 | 16.08 | " | .023 | 27.2 | " " | | 24 |
| 25 | 387 | 9.39 | .367 | 11.83 | 111. | 4.33 | 25.6 | .13 | 8.7 | | | 25 |
| 26 | 449 | 10.89 | .425 | 11.22 | 122. | 4.77 | " | " | 15.8 | | U. S. steamship Crusader. | 26 |
| 27 | 426 | 10.32 | .589 | 11.16 | 114.1 | 4.45 | 17.5 | .078 | 19.8 | Two upper rows of tubes plugged | | 27 |
| 28 | 698 | 14.1 | .582 | 11.22 | 158.2 | 6.54 | 24.2 | .14 | 19.4 | Area of openings in furnace doors, 128.4 sq. in. | | 28 |
| 29 | 700 | 14.15 | .585 | 11.1 | 157. | 6.49 | " | " | 19.9 | " " " " 108.1 " | | 29 |
| 30 | 728 | 14.71 | .607 | 10.9 | 160.3 | 6.62 | " | " | 18.3 | " " " " 90.7 " | | 30 |
| 31 | 776 | 15.67 | .647 | 10.75 | 168.4 | 6.96 | " | " | 17.7 | " " " " 25.6 " | | 31 |
| 32 | 723 | 14.6 | .603 | 10.73 | 156.6 | 6.47 | " | .124 | 17.4 | Ferrules in tubes. Air holes as in 28 | | 32 |
| 33 | 666 | 13.46 | .556 | 11. | 148. | 6.12 | " | .108 | 18.7 | " " " " | | 33 |
| 34 | 648 | 13.08 | .54 | 11.26 | 147.4 | 6.09 | " | .094 | 18.8 | " " " " | U. S. revenue steamer Miami. | 34 |
| 35 | 579 | 11.7 | .483 | 10.85 | 127. | 5.25 | " | .068 | 19. | " " " " | | 35 |
| 36 | 675 | 13.63 | .664 | 10.85 | 147.8 | 7.21 | 20.5 | .112 | 19.9 | Two lower rows of tubes plugged. Air holes as in 28 | | 36 |
| 37 | 588 | 11.88 | .707 | 11.31 | 134.3 | 7.99 | 16.8 | .084 | 21.5 | Four " " " " " " | | 37 |
| 38 | 516 | 10.42 | .795 | 10.77 | 112.2 | 8.56 | 13.1 | .056 | 21.4 | Six " " " " " " | | 38 |
| 39 | 594 | 11.79 | .495 | 11.3 | 135.5 | 5.6 | 24.2 | .14 | 21.7 | Air holes as in 28 | | 39 |
| 40 | 489 | 9.87 | .408 | 10.9 | 107.5 | 4.44 | " | " | 16.4 | " " | | 40 |

*Summary of Experiments with Boilers of Various Forms*—(Continued).

| Number for Reference. | Pounds of Combustible per Hour. Total. | Per Square Foot of Grate Surface. | Per Square Foot of Heating Surface. | Pounds of Water Evaporated, from and at 212°. Per Pound of Combustible. | Per Square Foot of Grate Surface, per Hour. | Per Square Foot of Heating Surface, per Hour. | Ratio of Heating to Grate Surface. | Draught Area to Grate Surface. | Per Cent. of Refuse. | Remarks. | | Number for Reference. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | **II.—Horizontal Fire-Tube Boilers, internally fired, of the Locomotive Type.** | | |
| 41 | 85 | 16.04 | .731 | 9.47 | 151.8 | 6.93 | 21.9 | .101 | 21.6 | Uncovered, extreme temperature 68.2° | Small locomotive boiler in open shed. | 41 |
| 42 | 82 | 15.5 | .707 | 11.49 | 178. | 8.13 | " | " | 22.8 | Covered with felt, extreme temperature 53.5° | | 42 |
| 43 | 762 | 14.1 | .495 | 10.2 | 143.8 | 5.05 | 28.5 | .183 | 16.9 | ........ | U. S. steamship Kansas. | 43 |
| 44 | 709 | 13.12 | .46 | 10.79 | 141.6 | 4.97 | " | .151 | 16.6 | Ferrules in tubes | | 44 |
| 45 | 712 | 13.18 | .462 | 10.79 | 142.2 | 4.99 | " | .123 | 18.2 | " " | | 45 |
| 46 | 581 | 10.75 | .378 | 11.57 | 124.4 | 4.37 | " | .097 | 18.7 | " " | | 46 |
| 47 | 314 | 6.68 | .16 | 10.3 | 68.8 | 1.62 | 42.6 | .149 | 5.2 | Lawrence Water-Works | | 47 |
| 48 | 529 | 9. | .26 | 10.1 | 90.8 | 2.67 | 34. | .119 | 2.4 | | | 48 |
| 49 | 694 | 4.72 | .208 | 11.32 | 51.5 | 2.27 | 22.7 | .15 | 15.1 | Waterman's experimental boiler | | 49 |
| | | | | | | | | | | **III.—Upper Return-Flue Boilers, internally fired.** | | |
| 50 | 982 | 15.21 | .723 | 8.54 | 129.8 | 6.15 | 21.1 | .2, .114 | 12.5 | U. S. steamship Shockokon | | 50 |
| 51 | 571 | 8.84 | .42 | 8.52 | 75.3 | 3.57 | " | " | 12.5 | | | 51 |
| 52 | 902 | 9.1 | .438 | 8.67 | 78.8 | 3.79 | 20.8 | .162, .116 | 11.1 | U. S. steamship James Adger | | 52 |
| | | | | | | | | | | **IV.—Double Return Drop-Flue Boilers, internally fired.** | | |
| 53 | 130 | 3.45 | .125 | 13.46 | 46.4 | 1.68 | 27.7 | .114, .083, .096 | 25. | U. S. steamship Whitehead | | 53 |
| 54 | 523 | 9.37 | .428 | 11.45 | 107.2 | 5. | 21.9 | .115, .107, .139 | 18.4 | U. S. steamship Morse | | 54 |
| | | | | | | | | | | **V.—Sectional or Water-Tube Boilers, externally fired.** | | |
| 55 | 184 | 6.8 | .308 | 10.53 | 71.5 | 3.59 | 22. | .071, .25, .111 | 22.7 | Howard boiler | | 55 |
| 56 | 411 | 12.43 | .244 | 9. | 111.8 | 2.2 | 50.8 | .063 | 9.3 | Exeter boiler | | 56 |
| 57 | 271 | 8.29 | .163 | 10.08 | 83.5 | 1.64 | " | " | 11.4 | | | 57 |
| 58 | 161 | 10.71 | .263 | 10.69 | 114.6 | 2.86 | 40. | .148 | 10.8 | "Acme" boiler | | 58 |
| 59 | 623 | 13.63 | .37 | 10.33 | 141.3 | 3.83 | 36.9 | .418, .264, .206 | 7.9 | Babcock & Wilcox boiler | | 59 |
| 60 | 396 | 8.69 | .2[illegible]5 | 11.87 | 103. | 2.79 | " | " | 10.2 | | | 60 |

*Summary of Experiments with Boilers of Various Forms*—(Continued).

| Number for Reference. | Pounds of Combustible per Hour: Total. | Pounds of Combustible per Hour: Per Square Foot of Grate Surface. | Pounds of Combustible per Hour: Per Square Foot of Heating Surface. | Pounds of Water Evaporated from and at 212°: Per Pound of Combustible. | Pounds of Water Evaporated from and at 212°: Per Square Foot of Grate Surface, per Hour. | Pounds of Water Evaporated from and at 212°: Per Square Foot of Heating Surface, per Hour. | Ratio of Heating to Grate Surface. | Ratio of Draught Area to Grate Surface. | Per Cent. of Refuse. | Remarks. | | Number for Reference. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | VI.—Externally-fired Boilers, Various Forms. | | |
| 61 | 269 | 4.89 | .134 | 12.18 | 59.6 | 1.57 | 37.9 | .118 | 7.7 | Lynn Water-Works, horizontal tubular | | 61 |
| 62 | 411 | 10.55 | .423 | 11.18 | 117.9 | 4.72 | 25. | .141 | 11.1 | Galloway boiler. | | 62 |
| 63 | 307 | 7.88 | .316 | 11.56 | 91.1 | 3.65 | " | " | 11.1 | | | 63 |
| 64 | 237 | 9.48 | 1.182 | 10.04 | 95.2 | 11.87 | 8. | .054 / .042 | 8.4 | Pierce boiler | | 64 |
| 65 | 178 | 7.12 | .888 | 10.14 | 72.2 | 8.99 | " | " | 11.6 | | | 65 |
| 66 | 362 | 14.47 | .813 | 12.2 | 176.5 | 3.82 | 46.2 | .13 | 9.3 | Smith boiler | | 66 |
| 67 | 270 | 10.8 | .232 | 12.23 | 132.1 | 2.86 | " | " | 11.1 | | | 67 |
| 68 | 1,338 | 11.89 | .296 | 10.65 | 126.7 | 8.15 | 40.2 | .21 / .168 / .351 | 11.3 | Brooklyn Water-Works, drop flue | | 68 |
| 69 | 188 | 12.6 | .356 | 11.75 | 147.5 | 4.5 | 36. | .213 / .143 | 9.9 | Cumberland coal | Hoyt furnace, drop-flue boiler. | 69 |
| 70 | 226 | 14.8 | .18 | 12.46 | 192.1 | 2.25 | 83. | " | 10.2 | " " Heater in chimney | | 70 |
| 71 | 229 | 15.3 | .43 | 11.69 | 178.4 | 4.92 | 86. | " | 20. | American Cannel coal from Ohio | | 71 |
| 72 | 160 | 5.9 | .22 | 9.56 | 54.1 | 2.04 | 27. | .1 | 30. | N. Y. Hospital, ordinary furnace, American Cannel | | 72 |
| 73 | 212 | 9.42 | .274 | 11.22 | 105.8 | 3.07 | 34.4 | .095 / .086 | 10.6 | Lowe boiler | | 73 |
| 74 | 136 | 6.06 | .175 | 11.87 | 71.7 | 2.08 | " | " | 11.3 | | | 74 |
| 75 | 335 | 16.36 | .549 | 10.13 | 166. | 5.57 | 29.8 | .404 / .41 / .373 | 11.8 | Ronchamp coal | Lancashire boiler. | 75 |
| 76 | 178 | 8.68 | .291 | 10.9 | 94.6 | 3.17 | " | " | 14.7 | " " | | 76 |
| 77 | 335 | 16.32 | .548 | 10.26 | 167.4 | 5.62 | " | " | 14.4 | " " | | 77 |
| 78 | 298 | 14.54 | .488 | 8.65 | 125.7 | 4.22 | " | " | 9.9 | Saarbrück " | | 78 |
| 79 | 317 | 17.27 | .57 | 10.02 | 173.1 | 5.71 | 30.3 | .443 / .252 | 14.1 | Ronchamp coal | Elephant boiler. | 79 |
| 80 | 186 | 9.26 | .306 | 10.76 | 99.5 | 3.28 | " | " | 14. | " " | | 80 |
| 81 | 309 | 15.39 | .508 | 8.66 | 133.2 | 4.4 | " | " | 9.1 | Saarbrück " | | 81 |
| 82 | 320 | 15.59 | .315 | 11.2 | 174.6 | 3.53 | 49.5 | .404 / .883 / .712 | 13.8 | Ronchamp coal | Fairbairn boiler. | 82 |
| 83 | 186 | 9.07 | .183 | 10.52 | 95.4 | 1.93 | " | " | 13.4 | " " | | 83 |
| 84 | 297 | 14.5 | .293 | 9.27 | 134.4 | 2.72 | " | " | 10.6 | Saarbrück " | | 84 |

Reference has already been made to two of these tables; and the third gives results of experiments with boilers where the proportions were varied, and with some of the principal varieties of boilers in use. All the experiments in these tables, with a few exceptions that are noted, were made with anthracite coal of good quality; and they were all conducted for a sufficient length of time to furnish valuable standards of comparison, with the exception of experiments 56–60, 62–67, 73 and 74, which lasted but 8 hours each, and are in some other respects less reliable than the remainder. Nearly all the experiments, however, it must be remembered, were made with clean boilers, and with firemen rather more skillful than the average; so that for ordinary practice, with boilers of similar design, the results are liable to be somewhat reduced.

It will be observed, in the third table of experiments, that in several instances there is more than one value of the ratio of calorimeter or draught area to grate-surface. This is because the calorimeter varied in different sections of the course of the gases. It also varied in some other instances that are not noted because the data could not be obtained; and in all instances where a single ratio is given, it refers to the tube or flue calorimeter for tubular or flue boilers, and to the most restricted section for other varieties. The experiments in the third table are taken from "Experimental Researches in Steam-Engineering," "Reports on Tests of the Lynn and Lowell Pumping-Engines," Van Nostrand's *Eclectic Engineering Magazine*, xiv., "Report of Boiler-Tests at the Centennial Exposition," and "Bulletin de la Société Industrielle de Mulhouse." The data are, however, in some instances more complete than in the original publications.

To properly discuss these experiments would require more space than is allowed, and the reader who desires to turn them to account will find them worthy of careful study. Some few hints as to methods can only be given. The table of experiments with the horizontal fire-tube boiler, for instance, can be rearranged so that the experiments take rank with respect to the total combustion per hour, the combustion per hour per square foot of grate-surface, or any other heading that is considered important, and, with each arrangement, some valuable facts will be disclosed. To give a single illustration, suppose it is required to design an horizontal fire-tube boiler for a slow rate of combustion—say, from 7 to 9 lbs. of combustible per square foot of grate per hour. Pick out all the experiments in the first table where the combustion is between these limits, and it will be found that about the same economy will be produced, whether the boiler be built of the ordinary proportions, or whether the heating surface and calorimeter are considerably reduced—so that the latter arrangement is to be preferred as the cheapest.

It is believed that these tables are sufficiently extended to aid in the design of a boiler for most circumstances that occur, and, in nearly every instance, the normal proportions given are representative of good practice, while the varied proportions frequently show how this practice can be improved.

The general conclusions that seem to be warranted by these experiments and others of a similar character can only be briefly alluded to. As boilers are ordinarily designed, the vertical water-tube boiler with the tubes above the furnace is the most economical, because it breaks up and mixes the gases most thoroughly. It is probable, however, that nearly any other form of boiler can be made to produce the same economy by a proper variation of calorimeter and heating surface. So far as mere economy of evaporation is concerned, therefore, it seems to be a matter of indifference which form is selected; but in regard to economy of construction, great variations will be found to exist.

The accompanying table will be found useful in proportioning the heating surface and calorimeter of tubular boilers. Its use will be readily understood by inspection:

*Dimensions of Boiler Tubes.*

| EXTERNAL DIAMETER. | | THICKNESS. | INTERNAL DIAMETER. | | EXTERNAL SURFACE, PER FOOT OF LENGTH. | | INTERNAL SURFACE, PER FOOT OF LENGTH. | | INTERNAL CROSS-SECTION. | | EXTERNAL DIAMETER. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| In Inches. | In Feet. | In Inches. | In Inches. | In Feet. | In Square Inches. | In Square Feet. | In Square Inches. | In Square Feet. | In Square Inches. | In Square Feet. | In Inches. |
| 1.25 | .1042 | .072 | 1.106 | .0922 | 47.1 | .3272 | 41.7 | .2896 | .96073 | .006672 | 1.25 |
| 1.5 | .125 | .083 | 1.334 | .111 | 56.5 | .3927 | 50.3 | .3492 | 1.3977 | .009706 | 1.5 |
| 1.75 | .1458 | .095 | 1.56 | .13 | 66.1 | .4582 | 58.8 | .4084 | 1.9113 | .013273 | 1.75 |
| 2. | .1667 | .095 | 1.81 | .1508 | 75.4 | .5236 | 68.2 | .4739 | 2.573 | .017868 | 2. |
| 2.25 | .1875 | .095 | 2.06 | .1717 | 84.8 | .5891 | 77.7 | .5393 | 3.3329 | .023145 | 2.25 |
| 2.5 | .2083 | .109 | 2.282 | .1902 | 94.2 | .6545 | 86. | .5974 | 4.09 | .028403 | 2.5 |
| 2.75 | .2292 | .109 | 2.532 | .211 | 103.7 | .72 | 95.5 | .6629 | 5.0352 | .034967 | 2.75 |
| 3. | .25 | .109 | 2.782 | .2318 | 113.1 | .7854 | 104.9 | .7283 | 6.0786 | .042213 | 3. |
| 3.25 | .2708 | .12 | 3.01 | .2508 | 122.5 | .8509 | 113.5 | .788 | 7.1158 | .049415 | 3.25 |
| 3.5 | .2917 | .12 | 3.26 | .2717 | 132. | .9163 | 122.9 | .8535 | 8.3469 | .057965 | 3.5 |
| 3.75 | .3125 | .12 | 3.51 | .2925 | 141.4 | .9818 | 132.3 | .9189 | 9.6762 | .067196 | 3.75 |
| 4. | .3333 | .134 | 3.732 | .311 | 150.8 | 1.0472 | 140.7 | .977 | 10.924 | .075964 | 4. |
| 4.5 | .375 | .134 | 4.232 | .3527 | 169.7 | 1.1781 | 159.5 | 1.1079 | 14.066 | .097683 | 4.5 |
| 5. | .4167 | .148 | 4.704 | .392 | 188.5 | 1.309 | 177.3 | 1.2315 | 17.379 | .12069 | 5. |
| 6. | .5 | .165 | 5.67 | .4725 | 226.1 | 1.5708 | 213.8 | 1.4844 | 25.25 | .17535 | 6. |
| 7. | .5833 | .165 | 6.67 | .5558 | 263.9 | 1.8326 | 251.5 | 1.7462 | 34.861 | .24265 | 7. |
| 8. | .6667 | .165 | 7.67 | .6392 | 301.8 | 2.0944 | 289.2 | 2.008 | 46.204 | .32086 | 8. |
| 9. | .75 | .18 | 8.64 | .72 | 339.3 | 2.3562 | 325.7 | 2.262 | 58.63 | .40715 | 9. |
| 10. | .8333 | .203 | 9.594 | .7995 | 377. | 2.618 | 361.7 | 2.5117 | 72.292 | .50203 | 10. |

When the calorimeter of a boiler is one-eighth of the grate surface, the best conditions for maximum combustion exist; and if a slow rate of combustion is employed, both calorimeter and heating surface can be reduced without loss of economical effect. There are many boilers in use to-day, burn-

ing coal at slow rates, that could have half their tubes plugged up, or could be made just so much smaller, and evaporate as much water as before; while, if the tubes were half as many and twice as long as for maximum combustion, thus reducing the calorimeter and preserving the heating surface, the economical effect would be increased.

Boilers set in brickwork are ordinarily less economical than those internally fired, on account of the greater loss by radiation.

The reader who consults the works from which these experiments are taken will find the above principles discussed at length.

The diameter of tubes to be chosen for any special case will depend upon their length. A good length for 3-inch tubes is 12 feet, and the diameter can be diminished or increased 1 inch for each decrease or increase of 4 feet in the length of the tube, and in similar proportion for any other variation in length. Thus, for tubes 4 feet long, the diameter may be $\frac{12}{4} \times 3 = 1$ inch, and for tubes 18 feet in length the appropriate diameter is $\frac{18}{12} \times 3 = 4\frac{1}{2}$ inches. These lengths are for maximum combustion; and when the rate is reduced, the tubes can be lengthened.

The proportions of water and steam room in boilers vary greatly. A ratio that is quite common in good practice is an allowance of 60 per cent. of the whole capacity of the boiler as water-room, and the remaining 40 per cent. as steam-room. In many instances the space is equally divided between steam and water room; and a less proportion of steam room than 40 per cent. of the whole capacity is not considered advisable, except in cases of slow combustion, as boilers with an insufficient supply of steam-room frequently prime.

*Priming* is the tendency of the water in the boiler to foam and pass in a state of spray into the cylinder along with the steam; and when in too great a quantity to escape through the steam-port in the return stroke, it infallibly breaks down the engine. This effect must invariably follow the priming of a sufficient quantity of water in the cylinder of a beam-engine in a factory, because it is not and cannot be expected to be calculated to withstand a sudden *blow*, and such it is in reality. For if the water primes into the cylinder in the down-stroke, it must remain on the top of the piston until it strikes against the cylinder cover in the up-stroke, with more or less violence according to the quantity. From the incompressibility of water, the effect is the same as if a piece of iron of equal thickness to the depth of water on the piston was suddenly inserted in its place. The tremendous effect sometimes produced when a large engine breaks down from this cause may easily be conceived; for, as the vacant space left for clearance at the top of the cylinder is generally about the same depth in large as in small engines, the intruding body of water strikes the cylinder-cover with a proportionately greater force. Generally the accident does not end with merely straining or breaking the crank-pin, which may be the extent of the injury in small engines; but the momentum of the beam is added to that of the fly-wheel, and their combined force is exerted directly in splitting the cylinder, or tearing off the cylinder-cover, thus effectually demolishing all the rods and gearing. Priming arises from insufficient steam-room, an inadequate area of water-level, or the use of dirty water in the boiler; the last of these faults may be remedied by the use of collecting-vessels, but the other defects are only to be corrected either by a suitable enlargement of the boiler, or by increasing the pressure and working more expansively. Closing the throttle-valves of an engine partially will generally diminish the amount of priming, and opening the safety-valve suddenly will generally set it astir. A steam vessel coming from salt into fresh water is much more liable to prime than if she had remained in salt water or never ventured out of fresh. This is to be accounted for by the higher heat at which salt water boils, so that casting fresh water among it is in some measure like casting water among molten metal, and the priming is in this case the effect of the rapid production of steam. One of the best palliatives of priming appears to be the interposition of a perforated plate between the steam-space and the water. The water appears to be broken up in dashing against a plate of this description, and the steam is liberated from its embrace. In cases in which an addition is made to a boiler or steam-chest, it will be the best way not to cut out a large hole in the boiler-shell for establishing a communication with the new chamber, but to bore a number of small holes for this purpose, so as to form a kind of sieve, through which a rush of water cannot ascend. In locomotives the same end is attained by the use of a perforated steam-pipe extending from end to end of the boiler. Such a contrivance draws the steam off equally from the surface instead of taking it from any one part; and boilers provided with it are enabled to work with so small a steam-space that the steam-domes are now being taken away from locomotives altogether. This expedient has not yet been adopted in steam vessels, though it appears to be applicable to them also with advantage. In some boilers priming appears to be mainly caused by a malformation which prevents the water from circulating freely, and the steam has therefore to pass up through the water, occasioning a great agitation, instead of the water being enabled to circulate with the ascending steam. The evil may be mitigated in such cases by the addition of pipes to the exterior of the boiler, which will permit a descending current to be established, to replace the water carried upward by the steam. This tendency of the water to rise into the cylinder is always considerably promoted by the very usual situation of the steam induction-pipe at the back end of the boiler, and seems to arise partly from the constant circulation of the water, which causes a current at the surface to set in the direction of the length of the boiler from the front end to the back. This circulation of water takes place in all oblong boilers, with a certain velocity depending on the ratio that the intensity of the heat in the furnace bears to the quantity of water to be kept heated, and is entirely independent of other causes, producing *waves*, which take their rise over the fire, and gradually increase in height as they pass toward the back part of the boiler.

*The term "horse-power,"* referred to a boiler, has no definite meaning. In the early days of the steam-engine, when there was little difference in the details of engines and boilers, it usually hap-

pened that a boiler large enough to furnish one engine with steam would answer for any other of the same size; and as the power of the early engines was in direct proportion to their size, a boiler of certain dimensions would furnish steam for an engine developing a definite horse-power, and hence was said to be a boiler of a certain horse-power. But, as improvements were introduced, and various forms of boilers and engines were adopted, it was found that the size of a boiler was not always a measure of its efficiency, and that different engines required very different quantities of steam to develop a given horse-power. Thus it frequently happens that what is a 10-horse-power boiler for one engine, or the boiler which furnishes steam to develop 10 horse-power in that engine, may only be a 5-horse-power boiler for a more wasteful engine. Under these circumstances, it is impossible to decide what the horse-power of a boiler is, in case of dispute. If, on the contrary, the rating of the boiler is based upon its evaporation under given conditions, a simple experiment will settle whether it is working up to its rating. The reader will find a good discussion of this subject in the "Reports of the Committee of the Franklin Institute on the Mode of determining the Horse-Power of Steam-Boilers." All the members of this committee agreed that the boiler should be rated according to its actual evaporation rather than by its dimensions; and while some members thought that a horse-power should correspond to an evaporation of 1 cubic foot of water per hour, from and at 212°, others considered that it was not advisable to adopt any standard for horse-power. This is probably the view of the majority of engineers.

*Testing Boilers.*—If the object of a boiler-test is simply to determine how much water can be evaporated under given circumstances by that boiler, it is only necessary to weigh the coal and feed-water, and ascertain the quality of the steam, in order to know whether the apparent evaporation correctly represents the performance. The trial should be continued for 24 hours at least, in order to obtain average conditions. It is a good plan, before commencing the trial, to raise steam in the boiler, then haul the fire, clean out the ash-pit, and start a new fire with wood, beginning the test as soon as the coal thrown in is kindled, and charging all the coal put into the furnace after the new fire is started. At the time of starting, the height of the water in the boiler should be noted, and it should be left at the same height on concluding. The fire should be maintained of uniform thickness throughout the trial, and not allowed to burn out toward the end; and at the time of closing the test, the fire should be hauled as rapidly as possible, and the weight of the contents of the furnace, in a dry state, should be taken at once. The weight of the contents of the ash-pit should be added to the above, and deducted from the total weight of coal, giving the weight of combustible consumed. In weighing out the coal, during the trial, it should be done at regular intervals, and a constant weight should be supplied each time, to avoid errors. The feed-water may be drawn from one or more tanks placed on platform scales, filled up and drawn down to the same weights each time, so that the total feed-water can be obtained at once from a tally of the number of tanks.

Having made these observations, if the water has been evaporated into saturated steam, the quotient obtained by dividing the weight of feed-water by the weight of combustible will give the result required. In the majority of well-designed boilers the result so obtained will be practically correct. This cannot be known in advance in any particular case, however, and it is important to determine the quality of steam furnished during the experiment. A simple and accurate method of making this determination will be explained. Provide a tank with an orifice at the bottom, and place within it a coil of thin pipe, the lower end of which is brought through the side of the tank near the bottom, and furnished with a cock. The upper end is to be connected, when in use, to the steam-space of the boiler. During the trial, steam is to be admitted to the coil through a well-felted pipe, and water to the tank to condense the steam, so that, knowing the pressure of steam, the weight and temperature of the condensed water, and the weight, initial and final temperature of the condensing water, the quality of the steam can be calculated. In order to determine the weight of condensing water, first ascertain, by experiment, how much water the orifice in the bottom of the tank will deliver for different heads of water in the tank, and, this once determined, it will only be necessary to observe the head in the tank during the experiment. Another preliminary experiment must be made with this apparatus to determine the heat lost by radiation and evaporation, which is ascertained by heating the water in the tank to temperatures similar to those used in the experiment, and noting the loss of temperature and weight for definite intervals of time. The pipe leading to the coil should be connected to the boiler at such a point that it obtains an average quality of steam. If it draws its supply from the centre of the steam-pipe, this will generally be accomplished. (Those who are specially interested in this question will find a very good discussion by Prof. Hirn, the inventor of the best plans in use, in the "Bulletin de la Société Industrielle de Mulhouse," 1869.) The manner of making the calculations from the data observed in connection with this instrument will be illustrated by an example. (Some of the constants required for the solution are taken from tables of the properties of steam and water, in the article STEAM.) Suppose that in a certain test the total weight of coal supplied to the furnace was 4,476 lbs., the weight of feed-water 34,700 lbs., and the weight of coal and ashes drawn from the furnace and ash-pit 795 lbs., so that the combustible was 4,476 — 795 = 3,681 lbs. Hence the apparent evaporation was $\frac{34,700}{3,681} = 9.4$ lbs. of water from the temperature of the feed per pound of combustible, if the steam was dry.

Suppose that an instrument was used for testing the quality of the steam, such as has been described, and that the observations were as follows: Pressure of steam by gauge, 70 lbs.; weight of steam condensed at temperature of 95°, 234 lbs.; initial temperature of condensing water, 64°; final temperature, 92°; head of water in tank, 24.5 inches; time of trial, 30 hours; and that previous experiments with the apparatus showed that, under the observed head, 4 cubic feet of water weighing 62.1 lbs. per cubic foot were discharged from the tank per hour, and that the loss of heat by radiation and evaporation from the tank was 1,422 thermal units per hour. Then the amount of heat im-

parted to the condensing water per hour was $4 \times 62.1 \times (92 - 64) + 1{,}422 = 8{,}377.2$ thermal units, and since $\frac{234}{30} = 7.8$ lbs. of steam were condensed per hour, each pound of steam imparted $\frac{8{,}377.2}{7.8} =$ 1,074 thermal units to the condensing water; and as the condensed steam was discharged at a temperature of 95°, the total heat required to condense a pound, and cool it to 32°, was $1{,}074 + 95 - 32 = 1{,}137$ thermal units. The total heat of a pound of dry steam above 32°, at the observed pressure, is 1,178.5 thermal units, so that the steam generated in the above experiment contained some moisture, the amount of which can easily be determined. Calling $w$ the heat of the water, corresponding to the observed pressure, $H$ the total heat of a pound of dry steam, $h$ the heat per pound, determined by experiment—all referred to 32°—the per cent. of moisture in the steam is $\frac{H-h}{h-w} \times 100 = \frac{1{,}178.5-1{,}137}{1{,}137-286.2} \times 100 = 4.9$. The proportion of dry steam in a pound of the mixture, calling $L$ the latent heat of the steam, is $\frac{h-w}{L} = \frac{1{,}137-286.2}{892.3} = 0.9535$ lb.

If the temperature of the feed-water in the above experiment was 64°, each pound of water would require $1{,}178.5 - 32 = 1{,}146.5$ thermal units for its conversion into dry steam, while the actual amount of heat imparted to each pound of water was $1{,}137 - 32 = 1{,}105$ thermal units. Hence the actual evaporation was $\frac{1{,}105}{1{,}146.5} = 0.9638$ of the apparent, and the actual evaporation from the temperature of the feed per pound of combustible was $9.4 \times 0.9638 = 9.06$ lbs., or $9.06 \times 1.18 = 10.69$ lbs. from and at 212°.

While an experiment similar to the above, if carefully performed, gives the exact data required of the performance of a particular boiler under special circumstances, it is not sufficiently in detail to be of much general value, since there is nothing to tell the circumstances under which this performance was realized, or to enable a comparison to be made with other boilers. Mr. Isherwood has well said that, if every engineer were to leave on record the particulars of a single *complete* experiment made by him, the science of engineering would be much more advanced than is actually the case. The reader who consults engineering literature in search of such experiments will be surprised to see how few complete records are to be met with. From the thousands of boiler-experiments, whose records have been published, there are very few that furnish much useful information, since it generally happens that the very data required for some important comparison are missing. The only way to avoid this, in making an experiment, is to give *all* the data, which, briefly expressed, comprise, in the case of a boiler-experiment, complete dimensions of the boiler, heating surface and how distributed, calorimeter, chimney dimensions, drawings of the boiler, all the data taken on the trial, all the constants and formulas used in the calculations, and a general discussion of the results. The data mentioned refer not only to weights, pressures, and temperatures, but also to any incidents that occur, however unimportant they may seem. In regard to the experiment, it should be made to include, if possible, temperature of furnace and chimney as well as of steam, air, and feed-water—the air-supply should be measured, and the products of combustion analyzed when practicable—and the effect of various rates of combustion and of varying the boiler proportions should be tried, if opportunity occurs. The kind of coal used should be described, its action noted, and, if practicable, its analysis given. It is by experiments such as these, as already shown, that the only true knowledge of correct boiler proportions can be obtained.

The importance of showing clearly the distribution of the heating surface will be evident from the consideration that the efficiencies of different parts vary so greatly. Thus, in the tubular boiler, as ordinarily designed, the heating surface in the furnace and back connection evaporates about 50 per cent. of all the water; and the first foot of the tubes exposed to the heated gases is sometimes more effective than all the remaining length. By giving the distribution of the heating surface, one of the causes of the efficiency or inferior performance of a particular boiler is frequently disclosed. The effect of varying the rate of combustion in a boiler gives results that are very useful for purposes of comparison. In the case of several boilers, whose durability and safety are equal, that one rates the highest which evaporates the most water per square foot of heating surface per hour, for a given rate of combustion per hour, referred to the same unit, for the reason that heating surface costs money. As results of tests are commonly stated and comparisons made, the evaporation of one boiler is compared with that of another, without any reference to the rate of combustion in each when referred to the heating surface; so that the results, when properly compared, might be reversed. This is sufficiently shown from the experiments recorded in another part of this article; and as it is sometimes important to make the reduction, a table calculated from Prof. Rankine's formula (see "Treatise on the Steam-Engine and other Prime Movers") is appended, by which the reduction can be effected approximately. Of course, whenever two different types of boilers are to be compared, they should be tried at the same rate of combustion per square foot of heating surface, if possible.

The feed-water heater referred to in this table is one located in the chimney, the heat being imparted to the water by the products of combustion.

*Example.*—In a certain competitive trial of two boilers, with heaters, and natural draught, the rate of combustion in the first was 0.5 lb. per square foot of heating surface per hour, and in the second 1 lb. The first evaporated 13.2 lbs. of water from and at 212° per pound of combustible, and the second 11.1 lbs., so that the first evaporated about 19 per cent. more than the second, under these conditions. If they had both been tried at the rate of combustion of the first, the second would have evaporated $\frac{.84}{.7} \times 11.1 = 13.32$ lbs., or would have been about 1 per cent. more efficient than the first.

Although the principles just stated for recording boiler experiments have not been followed in the records contained in this article, for the obvious reason of restricted space, an endeavor has been

made to give the results in a form sufficiently complete to render them useful in practice; and the reader who desires more detailed accounts will consult the references.

*Relative Efficiency for Different Rates of Combustion.*

| Pounds of Combustible per Square Foot of Heating Surface per Hour. | RELATIVE EFFICIENCY. | | | |
|---|---|---|---|---|
| | NATURAL DRAUGHT. | | FORCED DRAUGHT. | |
| | Boiler with Feed-water Heater. | Boiler without Feed-water Heater. | Boiler with Feed-water Heater. | Boiler without Feed-water Heater. |
| .1 | 1 | 1. | 1. | 1. |
| .2 | .955 | .946 | .971 | .969 |
| .3 | .913 | .906 | .945 | .941 |
| .4 | .875 | .861 | .919 | .911 |
| .5 | .84 | .827 | .896 | .888 |
| .6 | .808 | .79 | .873 | .865 |
| .7 | .775 | .761 | .851 | .844 |
| .8 | .75 | .729 | .831 | .824 |
| .9 | .724 | .705 | .811 | .805 |
| 1. | .7 | .678 | .792 | .78 |
| 2. | .525 | .503 | .644 | .632 |
| 3. | .42 | .397 | .542 | .528 |
| 4. | .35 | .33 | .468 | .456 |
| 5. | .3 | .282 | .412 | .399 |
| 6. | .263 | .246 | .368 | .356 |
| 7. | .233 | .218 | .332 | .321 |
| 8. | .21 | .196 | .303 | .292 |
| 9. | .191 | .178 | .278 | .268 |
| 10. | .175 | .163 | .257 | .247 |

*Construction of Boilers.*—The following rules, giving about one-eighth the ultimate strength of the material for the working strain, and following the proportions recommended by the best authorities, will be found useful in practice. They can readily be adapted to any other factor of safety greater or less than 8; but, taking into account the rapid deterioration of steam-boilers, and the violent strains to which they are frequently subjected, it is very questionable whether greater pressures or less thickness should be permitted, on principles of true economy. The reader will find interesting data relating to this subject in Fairbairn's "Useful Information for Engineers," Rankine's "Treatise on the Steam-Engine," Van Buren on the "Strength of Iron Parts of Steam Machinery," "Reports of the English Boiler Insurance Associations," "Proceedings of the Institution of Civil Engineers," xlvi., "Proceedings of the Institution of Mechanical Engineers," 1872, Grashof's "Festigkeitslehre," and "Des Ingenieur's Taschenbuch, von dem Verein 'Hütte.'"

*Notation.*

$K$ = diameter of rivet, in inches.
$v$ = length of rivet under head, in inches.
$l$ = lap to be given to joint, in inches.
$p$ = distance between centres of rivets, in inches.
$T$ = thickness of plate, in inches.
$P$ = working pressure of steam, in pounds per square inch.
$D$ = diameter of cylindrical shell, or flue, in inches.
$L$ = length of cylindrical flue, in inches.
$R$ = radius of circular plate, in inches.
$m$ = length of rectangular plate, and side of square plate, in inches.
$n$ = breadth of rectangular plate, in inches.
(Note that $m > n$.)
$S$ = distance between centres of stays, in inches.
$d$ = diameter of round stay, in inches.
$A$ = area or cross-section of stay, in square inches.

1. *Diameter of rivets.*

$$K = T \times \begin{cases} 2, & \text{for plates up to } \tfrac{3}{8} \text{ inch in thickness.} \\ 1.5, & \text{for plates from } \tfrac{3}{8} \text{ to } \tfrac{5}{8} \text{ inch in thickness.} \\ 1.25, & \text{for plates from } \tfrac{5}{8} \text{ to } \tfrac{3}{4} \text{ inch in thickness.} \\ 1.125, & \text{for plates from } \tfrac{3}{4} \text{ to 1 inch in thickness.} \end{cases}$$

2. *Length of rivets.*

$$v = 4.5 \times T.$$

3. *Distance between rivets.*

(*a.*) Single riveted joints.

$$p = T \times \begin{cases} 6, & \text{for plates up to } \tfrac{1}{4} \text{ inch in thickness} \\ 5, & \text{for plates from } \tfrac{1}{4} \text{ to } \tfrac{3}{8} \text{ inch in thickness.} \\ 4, & \text{for plates from } \tfrac{3}{8} \text{ to } \tfrac{5}{8} \text{ inch in thickness.} \\ 3, & \text{for plates from } \tfrac{5}{8} \text{ to 1 inch in thickness.} \end{cases}$$

(*b.*) Each line of rivets, double riveted joints.

$$p = T \times \begin{cases} 7, & \text{for plates up to } \tfrac{1}{4} \text{ inch in thickness.} \\ 6, & \text{for plates from } \tfrac{1}{4} \text{ to } \tfrac{7}{16} \text{ inch in thickness.} \\ 5, & \text{for plates from } \tfrac{7}{16} \text{ to } \tfrac{9}{16} \text{ inch in thickness.} \\ 4, & \text{for plates from } \tfrac{9}{16} \text{ to 1 inch in thickness.} \end{cases}$$

4. *Lap of joint.*

| | Single-riveted joint. | Double-riveted joint. | |
|---|---|---|---|
| $l = T \times$ | 6, | 10, | for plates up to $\frac{3}{8}$ inch in thickness. |
| | 4.5, | 7.5, | for plates from $\frac{3}{8}$ to $\frac{3}{4}$ inch in thickness. |
| | 4, | 6.7, | for plates from $\frac{3}{4}$ to 1 inch in thickness. |

5. *Working pressure for cylindrical shells.*

| | Single-riveted shells. | Double-riveted shells. | |
|---|---|---|---|
| $P = \frac{T}{D} \times$ | 10,000, | 12,000, | for steel shells. |
| | 7,600, | 9,000, | for wrought-iron shells. |
| | 5,000, | 6,400, | for copper shells. |

6. *Thickness of cylindrical shells.*

| | Single-riveted shells. | Double-riveted shells. | |
|---|---|---|---|
| $T = P \times D \times$ | 0.0001, | 0.00008333, | for steel shells. |
| | 0.0001316, | 0.0001111, | for wrought-iron shells. |
| | 0.0002, | 0.0001563, | for copper shells. |

7. *Working pressure for cylindrical flues of wrought-iron, exposed to external pressure.*

$$P = 1{,}950{,}000 \times \frac{T^2}{L \times D} \times \frac{a}{b \times c}.$$

8. *Thickness for cylindrical flues of wrought-iron, exposed to external pressure.*

$$T = \sqrt{\left(0.00000051282 \times P \times L \times D \times \frac{b \times c}{a}\right)}.$$

NOTE.—In the two foregoing formulas, the values of the constants, $a$, $b$, and $c$, are as follows:

| $a =$ | | |
|---|---|---|
| 0.4 | for flues from .061 to .087 in. thick. | |
| 0.45 | " " .087 " .119 " | |
| 0.5 | " " .119 " .159 " | |
| 0.55 | " " .159 " .206 " | |
| 0.6 | " " .206 " .261 " | |
| 0.65 | " " .261 " .325 " | |
| 0.7 | " " .325 " .399 " | |
| 0.75 | " " .399 " .483 " | |
| 0.8 | " " .483 " .577 " | |
| 0.85 | " " .577 " .682 " | |
| 0.9 | " " .682 " .8 " | |
| 0.95 | " " .8 " .931 " | |
| 1. | " " .931 " .107 " | |

| $b =$ | |
|---|---|
| 0.75 | for flues from 13 to 25 inches long. |
| 0.7 | " " 25 " 51 " |
| 0.65 | " " 51 " 110 " |
| 0.6 | " " 110 " 253 " |
| 0.55 | " " 223 " 628 " |

| $c =$ | |
|---|---|
| 1.2 | for flues from 2.4 " 4 in. in diameter. |
| 1.3 | " " 4. " 6.5 " " |
| 1.4 | " " 6.5 " 10.2 " " |
| 1.5 | " " 10.2 " 15.5 " " |
| 1.6 | " " 15.5 " 22.9 " " |
| 1.7 | " " 22.9 " 33. " " |
| 1.8 | " " 33. " 47. " " |
| 1.9 | " " 47. " 65. " " |

9. *Working pressure for flat plates, secured at the edges.*

| | Cast-iron plates. | Wrought-iron plates. | Steel plates. |
|---|---|---|---|
| (*a.*) Circular plates. | | | |
| $P = \frac{T^2}{R^2} \times$ | 3,750 | 9,000 | 15,000 |
| (*b.*) Rectangular plates. | | | |
| $P = \frac{T^2 \times (m^4 + n^4)}{m^4 \times n^2} \times$ | 5,000 | 12,000 | 20,000 |
| (*c.*) Square plates. | | | |
| $P = \frac{T^2}{m^2} \times$ | 10,000 | 24,000 | 40,000 |

10. *Thickness for flat plates, secured at the edges.*

| | Cast-iron plates. | Wrought-iron plates. | Steel plates. |
|---|---|---|---|
| (*a.*) Circular plates. | | | |
| $T = R \times \sqrt{P} \times$ | 0.018257 | 0.011785 | 0.0091287 |
| (*b.*) Rectangular plates. | | | |
| $T = m^2 \times n \times \sqrt{\left(\frac{P}{m^4 + n^4}\right)} \times$ | 0.014142 | 0.0091287 | 0.0070711 |
| (*c.*) Square plates. | | | |
| $T = m \times \sqrt{P} \times$ | 0.01 | 0.006455 | 0.005 |

11. *Working pressure for stayed surfaces.*

| | Copper plates. | Wrought-iron plates. | Steel plates. |
|---|---|---|---|
| $P = \frac{T^2}{S^2} \times$ | 17,000 | 27,000 | 45,000 |

12. *Thickness for stayed surfaces.*

| | Copper plates. | Wrought-iron plates. | Steel plates. |
|---|---|---|---|
| $T = S \times \sqrt{P} \times$ | 0.00767 | 0.0060858 | 0.0047141 |

13. *Working pressure for stays.*

| | Wrought-iron stays. | Copper stays. |
|---|---|---|
| $P = \frac{A}{S^2} \times$ | 4,000 | 3,000. |

14. *Area of stays.*

| | | |
|---|---|---|
| $A = P \times S^2 \times$ | 0.00025 | 0.000333. |

15. *Diameter of stays.*

$$d = \sqrt{(1.2732 \times A)}.$$

The following table for converting vulgar fractions into decimals will be found useful in connection with these rules.

| Halves. | Fourths. | Eighths. | Sixteenths. | Decimals. |
|---|---|---|---|---|
| | | | 1 | .0625 |
| | | 1 | 2 | .125 |
| | | | 3 | .1875 |
| | 1 | 2 | 4 | .25 |
| | | | 5 | .3125 |
| | | 3 | 6 | .375 |
| | | | 7 | .4375 |
| 1 | 2 | 4 | 8 | .5 |
| | | | 9 | .5625 |
| | | 5 | 10 | .625 |
| | | | 11 | .6875 |
| | 3 | 6 | 12 | .75 |
| | | | 13 | .8125 |
| | | 7 | 14 | .875 |
| | | | 15 | .9375 |
| 2 | 4 | 8 | 16 | 1. |

*Examples.*—1. For a single riveted joint of $\frac{1}{8}$-inch plates, the diameter of rivets $= 0.125 \times 2 = 0.25$ inch.

2. For the same joint, the length of rivet under the head $= 0.125 \times 4.5 = 0.5625$ inch.

3. For a double riveted joint of $\frac{1}{2}$-inch plates, the distance between centres of rivets in each row $= 0.5 \times 5 = 2.5$ inches.

4. The lap to be allowed for a single riveted joint of $\frac{1}{4}$-inch plates $= 0.25 \times 6 = 1.5$ inch.

5. The working pressure for a cylindrical boiler, 32 inches in diameter, made of wrought-iron plates $\frac{1}{4}$ inch thick, single riveted, $= \frac{0.25}{32} \times 7600 = 59.375$ lbs. per square inch.

6. The thickness for the plates of a cylindrical boiler, double riveted, 60 inches in diameter, made of copper plates, for a working pressure of 40 lbs. per square inch, $= 60 \times 40 \times 0.0001563 = 0.375$ inch.

Note.—In the double riveting to which these rules apply, the two rows of rivets are staggered, that is, the rivets of one row are midway between those of the other. The rules are designed for shells that are truly cylindrical, a condition that is only approximately fulfilled with the ordinary lap joint. In some instances cylindrical shells are constructed with butt joints, covering strips uniting the two plates. These rules refer to the resistance of a boiler to longitudinal rupture; and as the resistance to transverse rupture is twice as great, it is not uncommon to make the joints in cylindrical shells double riveted in the longitudinal seams, and single riveted in the others.

7. The working pressure for a cylindrical flue of wrought-iron, 20 inches in diameter, 80 inches long, three-eighths of an inch thick, exposed to external pressure, $= 1{,}950{,}000 \times \frac{(0.375)^2}{80 \times 20} \times \frac{0.7}{0.65 \times 1.6} = 115.35$ lbs. per square inch. If the flue were 120 inches long, the other conditions being the same, the working pressure $= 1{,}950{,}000 \times \frac{(0.375)^2}{120 \times 20} \times \frac{0.7}{0.6 \times 1.6} = 83.42$ lbs. per square inch. Since the strength of a flue decreases as its length is increased, it is customary, in the construction of a flue having a large diameter and considerable length, to divide it into a series of short flues, by attaching bands or stiffening pieces at short intervals, usually bands of angle-iron secured to the flue by socket bolts.

8. The thickness for a wrought-iron flue, 30 inches diameter, 40 inches long, exposed to an external pressure of 60 lbs. per square inch $= \sqrt{\left(0.00000051282 \times 60 \times 40 \times 30 \times \frac{0.7 \times 1.7}{.26}\right)} =$

0.26 inch. In this example it will be seen that one of the constants has to be determined by trial, since it depends on the thickness of the plate, which is unknown.

9. The working pressure for the flat head of a cylindrical boiler, unstayed, 20 inches diameter, made of wrought-iron half an inch thick, $= \frac{(0.5)^2}{(10)^2} \times 9{,}000 = 22.5$ lbs. per square inch.

10. The thickness for a steel plate, unstayed, 12 inches square, exposed to a pressure of 40 lbs. per square inch, $= 12 \times \sqrt{40} \times 0.005 = 0.38$ inch.

11. The working pressure for a wrought-iron plate, stayed at intervals of 7 inches, and three-eighths of an inch thick, $= \frac{(0.375)^2}{(7)^2} \times 27{,}000 = 77.48$ lbs. per square inch.

12. The thickness for a steel plate, exposed to a pressure of 100 lbs. per square inch, with stays 5 inches from centre to centre, $= 5 \times \sqrt{100} \times 0.0047141 = 0.24$ inch.

13. The working pressure for copper stays, having an area of 0.5 square inch, and placed 8 inches between centres, $= \frac{0.5}{(8)^2} \times 3000 = 23.4$ lbs. per square inch.

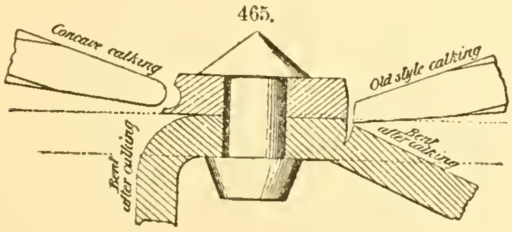
14. The area for wrought-iron stays, 5 inches between centres, for a pressure on the plate of 100 lbs. per square inch, $= 100 \times (5)^2 \times 0.00025 = 0.625$ square inch.

15. The diameter of a round stay, whose area is 0.625 square inch, $= \sqrt{(1.2732 \times 0.625)} = 0.892$ inch.

As before remarked, if these rules are to be changed so as to give the proportions with a different factor of safety, the change can easily be made by altering the constants. Thus, if a boiler is to be proportioned with only five-eighths as much strength as these rules give, multiply the constants in the rules for working pressure by $\frac{5}{8}$.

Riveting machines are generally used in the construction of modern boilers with plates more than half an inch thick. The riveted joints, whether hand or machine riveted, are then made tight by chipping and calking the seams. Sometimes the edge of the sheet that is to be calked is planed before the joint is made.

465.



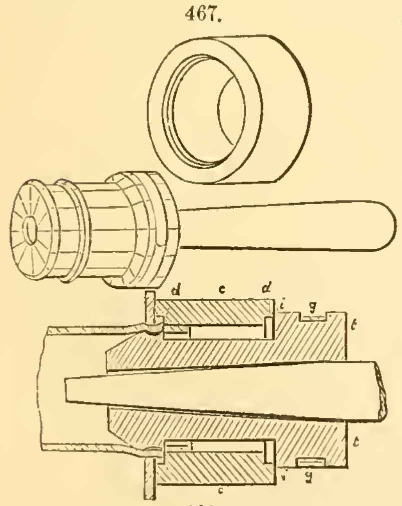

An important improvement in the mode of calking joints has recently been introduced. It is illustrated in Fig. 465, which sufficiently shows the nature of the improvement.

Where holes are cut in boilers for man and hand hole plates, and for connection with steam-drum, the sheet should be strengthened by a band around the edges of the opening, which band should be of angle-iron in the case of large openings.

Any pipe that is attached to a boiler should be secured by flanges in preference to being screwed into threads cut in the sheet.

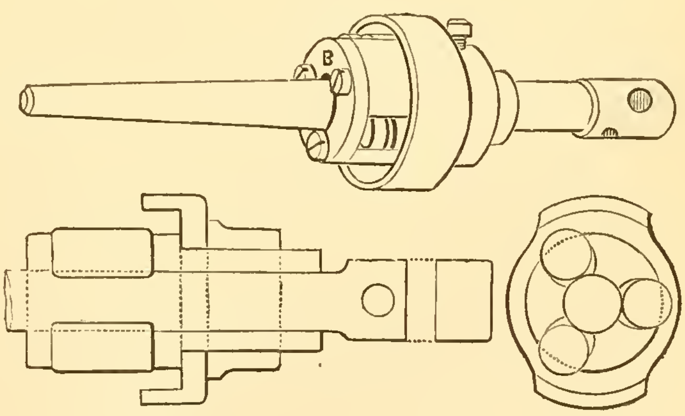
The tubes of boilers are secured to the tube-sheets by expanding them slightly at the inner or outer or at both edges of the sheets. Formerly this was done with a hand-tool and light hammer, but tube-expanders are now employed almost exclusively. The two forms in common use are Prosser's,

467.



466.

468.




Figs. 466 and 467, and Dudgeon's, Fig. 468. The former, it will be seen, consists of an expanding hollow plug, in sections held together by a spring. In using this tool, it is inserted into the end of the tube, and expanded by the action of a tapering mandrel driven into it, turning the expander slightly after each blow. A collar, Fig. 467, is sometimes used in connection with this tool, which cuts off the end of the tube while it is being expanded. From the form of the sections, this tool expands the tube on the outside of the sheet, as well as the inner.

The Dudgeon expander has a series of rollers which expand the tube when forced outward by the action of a tapering mandrel, which needs only to be turned a few times to do the work. It is stated that this tool has been used to stop leaks in tubes, with steam in the boiler.

*Incrustation and Corrosion.*—The action of the filtering feed water heater, which removes the solid

impurities from the water before it enters the boiler, has already been referred to. This device proves very efficacious in many instances, but there are some qualities of feed-water that cannot be purified in this manner. None of the water used in marine boilers can be rendered pure by mechanical means; and where surface-condensers are not employed, it is found impossible to prevent incrustations forming on the sheets and flues. The scale or incrustation on the heating surfaces of a boiler, being a bad conductor, reduces the evaporative efficiency; and if it is very thick, the material of the boiler frequently becomes overheated, and is thus rendered worthless. There are many so-called scale-preventives in the market, most of which, however, should be used with caution, since it is difficult to find anything that will attack incrustations, that is not also liable to injure the iron. An account of a number of these preparations, with their analysis, is contained in a "Report on Water for Locomotives and Boiler Incrustations," by C. F. Chandler. Among the best preventives, in the case of spring waters, are crude petroleum, soda ash, and tannate of soda. In using any of these remedies, the boiler should be blown off and washed out frequently. The scale can frequently be softened by allowing the water to remain in the boiler after the fire is hauled, until it is quite cool, and then letting it run out. Preparations which act mechanically and soften the scale have been used with some success. Tobacco-juice was tried for some time in vessels of the United States navy, and it was found that, while the amount of deposit was not diminished, it could be more easily removed. (See "Experimental Researches in Steam Engineering.")

At the present time, surface-condensers are used with nearly all marine engines, and, in general, the amount of incrustation is not great. With the first introduction of the surface-condenser, however, a greater evil than that of incrustation was developed, which at one time threatened to prevent the further use of this form of condenser. It was found that the interior of the boiler, where a surface-condenser was employed, corroded very rapidly, particularly in spots over the fire, so that in a few months the crown-sheet was nearly eaten through in places. Although the cause of this corrosion is not definitely known, it is believed to be due to the action of the grease which is carried from the cylinder into the boiler, and possibly in a slight degree to galvanic action between the brass tubes of the condenser and the iron of the boiler. Whether or not this is the true reason, an effective remedy has been discovered, which consists in tinning the condenser tubes, and allowing a very thin coating of scale to form on the interior surfaces of the boiler. As this scale, when deposited from salt-water, is sometimes dissolved, Mr. F. J. Rowan recommends that an artificial coating be produced, by feeding in a thin whitewash of calcium sulphate and magnesium hydrate.

In this brief notice of corrosion and incrustation, it has only been possible to touch upon the most prominent points. For useful information on this subject, reference is made to the "Reports of the Hartford Boiler Insurance Association," and "Boiler Incrustation and Corrosion," by F. J. Rowan.

*Boiler Explosions.*—At the present time there are numerous companies that are willing, for a small premium, to insure a steam-user against loss from boiler explosions, and that succeed, by a rigid system of inspection, in preventing nearly all accidents to boilers under their charge. The boiler insurance companies of England have, for a number of years, made a careful investigation into the circumstances attending every boiler explosion occurring in that country, so that the ultimate causes of such accidents are no longer in doubt. Explosions occur because the steam pressure is allowed to exceed the proper limit, or because the boiler, weakened in some manner, is no longer able to sustain the ordinary working pressure. The mysterious theories in regard to boiler explosions, that were formerly prevalent, are accepted by few intelligent engineers at present. Many of them have been directly disproved by experiments (see *Journal of the Franklin Institute*, 1836, 1837, 1872); but the most convincing proof is the fact that these explosions do not occur when boilers are properly managed. The investigations of boiler-insurance companies show that the proper pressure is often exceeded in a boiler, on account of the use of a defective steam-gauge or a so-called safety-valve that is too small to relieve the boiler, is overloaded, or stuck to the seat. One of the most noteworthy explosions that ever occurred from a defective safety-valve was on the British steamer Thunderer, July 17, 1876. (For an account of this explosion, and the thorough investigation that followed, see *Engineering*, xxii.)

A boiler becomes weakened, so that it will not sustain the ordinary working pressure, by corrosion, internal or external, by being overheated, which is frequently caused by incrustation, by grooving of the plates, caused by unequal expansion, or on account of lack of adjustment of the braces. All these points have been thoroughly investigated by the different boiler-insurance associations, and much valuable information is contained in their reports. (For an account of government regulations in various countries in regard to the inspection of steam-boilers, see *The Engineer*, xxxix.) The general result of all the investigations is to show that safety from accident can only be assured by thorough inspection at frequent intervals, and that the hydrostatic test alone is not sufficient, cases being on record in which a boiler has exploded at less than the pressure attained just before in a hydrostatic test. Indeed, the hydrostatic test, with cold water, often injures a boiler; and it is preferable to fill the boiler with water, load the safety-valve to the desired pressure, and heat the water gradually until it opens the valve by expansion. There are many defects, however, that this kind of test does not show, and that can only be discovered by careful inspection, external and internal. In this inspection, the eye must be assisted by the ear, one of the most delicate tests being the sound of the material when tapped with a light hammer. In the case of the disastrous explosion on the steamer Westfield, July 30, 1871 (see *Journal of the Franklin Institute*, 1871), the sheet was weakened by corrosions, a fact that was not disclosed by the hydrostatic test made a short time before, and that could only have been discovered by the hammer-test, according to the testimony of an experienced inspector. In the practice of private boiler-insurance associations, the hydrostatic test now occupies a secondary position, being used mainly in the case of new boilers, while personal inspection with the hammer-test is the rule for boilers that have been in service for some time. R. H. B.

BOILERS, SUGAR. See SUGAR-MAKING MACHINERY.

BOLSTERS are used to support a piece of work at a proper distance above an anvil while being punched or drifted: consequently, the greater the length of drift that protrudes beyond the work, the greater is the height or thickness of the bolster. Some sorts of bolsters consist of thick circular wings having holes of various diameters; other bolsters are slotted or may have a long narrow gap. The forging of one of this class consists in bending one end of a long bar and closing the work together until the gap is of the proper width. After the bolster is finished, it is cut from the bar, which serves as a handle during the forging.

BOLT-MAKING MACHINERY. See NAIL-MAKING MACHINERY.

BOLTS. See MILLS, GRAIN.

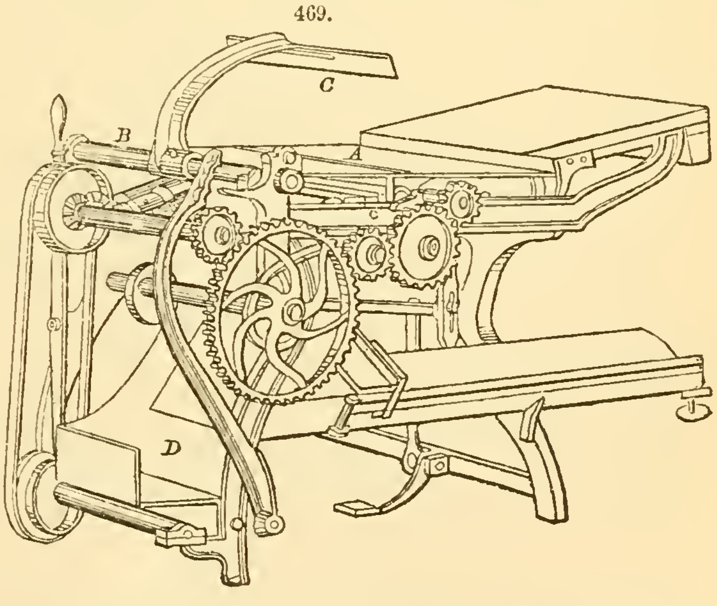
BOND. See MASONRY.

BONE-BLACK APPARATUS. See SUGAR-MAKING MACHINERY.

BOOKBINDING MACHINERY. There are two kinds of bookbinding, known respectively as "cloth-case" and "extra." The first is the cheapest, and that in which machinery is employed; the second is usually done by hand. After printing, the sheets go to the binder in quires, and are folded at the rate of from 10,000 to 12,000 per day in folding machines (see BOOK-FOLDING MACHINE). The sheets are then laid in piles, collected in sets to form the book, examined, and pressed in a smashing machine (see PRESS). The volume next passes to the sawing machine preparatory to sewing. Several volumes are taken together, and in an instant five revolving saws make as many cuts in the backs, of a size sufficient to admit the bands of twine to which the sheets are sewed. A late improvement in sawing sheets consists in gathering the sheets of a set in two heaps, odd signatures in one pile, even in the other. Slanting cuts are then made in the backs. The result is that when the sheets are gathered in proper sequence, the cuts cross, the binding-thread passing through the continuous orifice formed by their intersection. This is claimed to give a very strong binding. Book-sewing is now mainly done on book-sewing machines (see SEWING MACHINES). This done, end papers are pasted on the book, and its free edge is cut in a cutting machine (see PAPER-CUTTING MACHINERY). A backing machine then spreads the back and forms a groove for the boards. The cover is prepared of millboard and cloth, and stamped in an embossing press (see PRESS). Finally, the book is pasted on the sides, placed in the cover and pressed until dry. A very complete description of the hand-processes for both cloth-case and extra binding will be found in the article "Bookbinding," in the "American Cyclopædia."

BOOK-FOLDING MACHINE. An apparatus for folding sheets of books for sewing and binding. In Fig. 469 is represented a simple form of the Chambers machine. The operator transfers a sheet to the table *A*, which has a transverse slit across its middle. The revolution of the pulleys operates a rock-shaft *B*, carrying a curved arm with a folder *C* at its extremity, which presses the sheet down through the slit in the table, where it passes between rollers which double it and deliver it into a receptacle *A* at the end of the machine. To fold an octavo, the once-folded sheet is again presented to a folding edge, when it is carried to a second set of rollers which squeeze it flat, and it is thence led to a trough, where the folded sheets are collected.

469.




BOOT-MAKING MACHINERY. See SHOE-MAKING MACHINERY.

BORING MACHINE. See DRILLING AND BORING MACHINES.

BORT. See DIAMOND.

BOSHES. See FURNACES, BLAST.

BOTTLE-MAKING. See GLASS-MAKING MACHINERY.

BRACE, DRILL. See DRILLS.

BRAKE. This term is applied—(1) to a machine for separating the bark and pith from the fibre of hemp and flax; (2) to a kneading-machine (see BREAD AND BISCUIT MACHINERY); (3) to the handles of a fire-engine pump; (4) to an iron crotch with a sharp reëntering angle, used in basket-making, to peel the bark from the osiers; (5) to a heavy snaffle used for subduing unruly horses; (6) to a frame for confining refractory animals while being shod, etc.; (7) to a friction strap, band, or shoe, applied to machinery to afford resistance (see DYNAMOMETERS); (8) to a vehicle for breaking horses, consisting of the running-gears and a driver's seat, without any carriage-body. Brakes for wagons consist of rubbers or shoes so arranged as to be pressed against the wheels by a system of levers operated by a handle near the driver's seat. Sled or sleigh brakes are usually spurs brought into action by scraping on the ground.

BRAKES, CAR. These are the subject of numerous inventions, the result aimed at being to stop a railway train within the shortest possible distance. When the brakes are applied to a railway train to stop its motion entirely, the propelling or tractive force is taken off at the same moment; and their object is then to convert the *vis viva* of the train into mechanical work by means of friction, the result being heat.

Railway brakes are single or non-continuous when they are applied to a car singly, and continuous when they act simultaneously on all or on several cars of the train. There are also continuous and

automatic brakes; or, more properly speaking, some of the continuous brakes, under certain circumstances, can be made to work automatically. In all cases the braking force is applied to the wheels, blocks of metal being pressed against their rim, creating friction. The difference between the various brakes exists only in the manner in which this force is transmitted to the blocks—commonly called *shoes*—from the motor, whether the latter be steam or air pressure, the force of gravitation, or human strength.

Hand-Brakes.—The ordinary hand-brake is operated by a brakeman from the platform or the roof at either end of the car. It consists of a vertical rod supported and kept in position by brackets. On the upper end of the rod is a hand-wheel, and to the lower end a chain is attached, which, when wound up on the rod, acts on two horizontal wooden bars, suspended from the frame of the car-truck or the car, their ends being fitted with metallic friction-blocks, which press against the wheels. The vertical rod is held stationary by means of a small ratchet-wheel and detent on the platform or the roof when the brakes are put on, and is released when the motion of the train is stopped. There are various other forms of hand-brakes. Screw-brakes are often used on locomotives, in which the bar carrying the friction-blocks is pressed against the wheels by means of a rod, the other end of which is attached to one arm of a bell-crank; the other arm of the crank is pulled by a rod provided with a screw-thread working in a fixed nut. Pressure on brake-blocks is sometimes exerted simply by the weight of the brakeman, who stands at one end of a lever acting on the bars.

As the speed of railway trains has been increased, the necessity for better devices to effect quick and powerful action of brakes has augmented; and thus steam or other pressure has been substituted for human strength, and continuous brakes have been invented, all tending to increase safety and prevent accidents. Abundant instances may be cited wherein the safety or destruction of a fast train has depended upon whether two seconds or eighteen elapsed between the application of the brake and the development of the retarding force on the wheels.

M. Marié has determined that a theoretically perfect brake should stop a train running at 38 and 50 miles an hour respectively within the following distances:

| | | |
|---|---|---|
| In bad weather.................................... | 767 feet and | 1,377 feet. |
| In medium weather............................... | 387 " | 715 " |
| In fine weather.................................... | 259 " | 300 " |
| Under best conditions............................ | 197 " | 344 " |

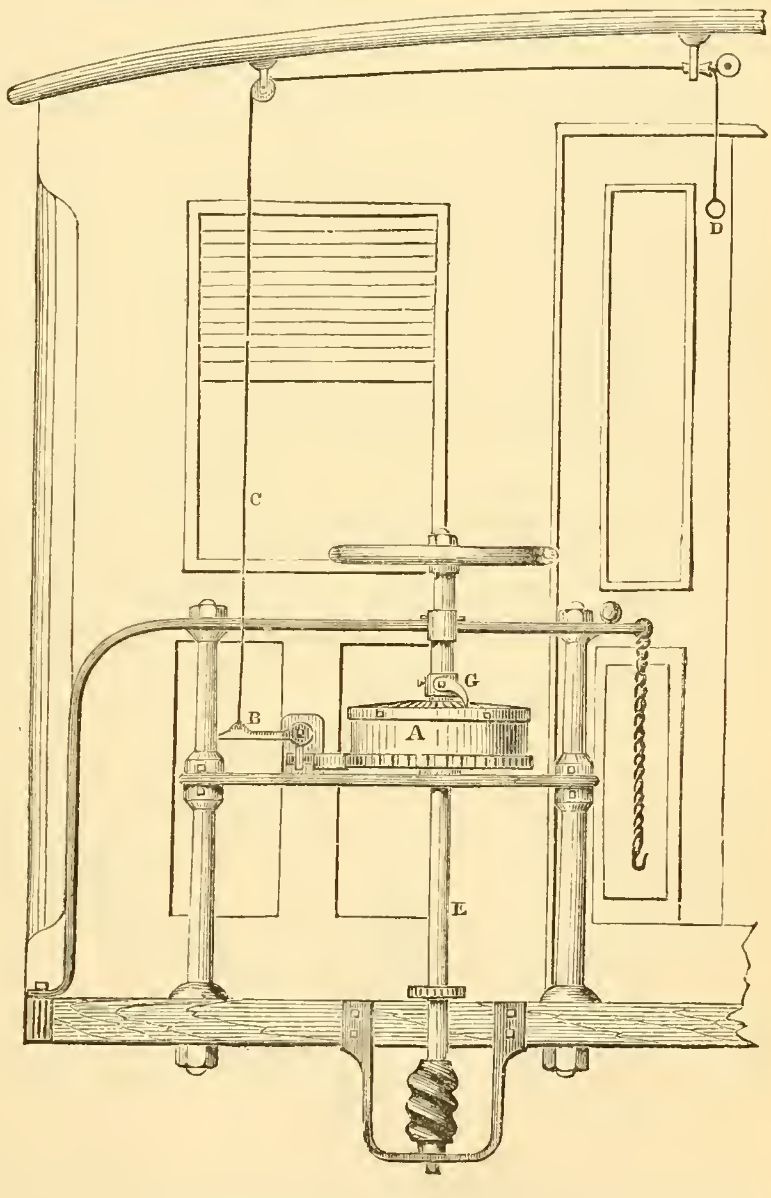
In order to determine the space in which quick stops could be effected by means of the tender-brake, application of brake to rear car, use of sand on rails, and reversal of engine, Captain Tyler, in 1875, caused the following trials to be made on the Derby, Castle Donnington & Trent line, England. There were four trials. In the first all available means were used to stop the train, viz.: tender-brake and one guard's van-brake at rear of train applied, sand used, and engine reversed, and steam against it with the Lechatelier tap open. The gradient was level; the train, the total weight of which was 102 tons 7 cwt. 2 qrs., was running at the rate of 49.9 miles per hour when the brake was applied. The result was that 54 seconds were occupied in stopping the train, which, after the application of the brake, ran a distance of 807 yards. In the second experiment all available means except reversing the engine were used: gradient, 1 in 330, up, and level; speed, 49.9 miles; time, 60 seconds; distance run, 843 yards. In the third experiment all available means were used, and when the engine was reversed, the regulator was allowed to remain wide open all the time: gradient, 1 in 220, down; speed, 52.5 miles; time occupied, 55 seconds; distance run, 867 yards. In the final experiment all available means were used. When reversing the engine the steam was first shut off, then the lever was pulled into back gear, and then steam was turned on again as in the first experiment: gradient, level; speed, 52.5 miles; time, 50 seconds; distance, 787 yards. The weather was fair, and the rails slightly greased. This will suffice to show the efficacy of the old system of brakes when aided by quick reversal of the engine.

Steam-Brakes.—These consist either of apparatus independently attached to the locomotive, or of mechanism which, besides transferring the propelling power, is also employed to retard the motion. An example of the first kind is a steam-cylinder placed on the locomotive between the driving-wheels, with two pistons and rods projecting in opposite directions, and acting on the friction-blocks. Steam admitted between the two pistons, through a pipe provided with a cock leading from the boiler, presses on the blocks, and is exhausted at the will of the driver through a separate cock. The second kind of steam-brakes is not used in this country. They continue to be employed in Europe, although they are far from being as effective as continuous brakes are. Of these there are several types: 1. In the Lechatelier system a pipe is led from the exhaust-pipe of the engine to a small closed vessel which is connected with the boiler by two other pipes, each furnished with a cock. One of these communicates with the boiler above and the other below the water-line, and by means of them a mixture of steam and water can be introduced into the closed vessel, and from it led by the pipe first mentioned to the exhaust-pipe. This provides for the admission of a mixture of steam and water into the blast-pipe when the engine is reversed, and the pistons then pump this mixture instead of air and dust (the latter of which would damage the working portions) into the boiler. 2. The method proposed by Zeh involves the compression of the steam, by shutting the exhaust-pipe, and placing the valve-gear on a high grade of expansion; thus the steam has to perform but little work, and the escape of the expanded steam is also prevented, and the latter is thus compressed at the backward stroke of the piston. 3. The compression of air in the cylinders has been proposed by M. de Bergues as a locomotive brake. The regulator and the blast-pipe are shut; the admission-pipe is connected with an air-vessel, which has a safety-valve; the exhaust-pipe is put in communication with the atmosphere; and the valve-motion is reversed. The counter-pressure is thus increased to a certain degree independently of the pressure in the boiler; but the disadvantages are many. 4. M. de

Landsee's brake acts upon the principle of producing the retarding power by using steam from the boiler as a back pressure upon the pistons in a more advantageous manner than with the reversing of the valve-gear. The steam in front of the piston is pressed back into the boiler, and acts thus by its repression upon the piston in comparison with the compression produced in the cylinder. 5. Krauss & Co.'s plan consists in an arrangement by means of which the steam can be made to enter the cylinders through the exhaust-pipes, instead of through the ordinary steam-pipes, the blast nozzle being at the time closed, and the steam admitted through the exhaust-pipes being pumped back partly into the boiler, and partly into the steam chests, from which it escapes through an adjustable valve into the chimney. Of course the engine is not reversed as in the Lechatelier device.

Continuous Brakes.—The main requirements to be sought for in selecting a railway-brake which may be placed with confidence upon high-speed trains may be summarized as follows: 1. It must be capable of application to every wheel throughout the train, if so desired. 2. It must be so prompt in its action that no appreciable loss of time occurs between the time of its application, and the moment when its full power can be exerted throughout the train. 3. It must be capable of being applied by the engineer, and at any desired point throughout the train. 4. It must be capable of application by engineer and train-guards acting in concert, or by either independently of the other. 5. It must under all circumstances be capable of arresting the motion of a train in the shortest possible distance. 6. It must be so arranged that in the event of the failure of any one of its vital parts, such failure must record itself by the application of the brakes or otherwise; so that the train, if in motion, may be automatically arrested, and the existence of a defect be thereby made known. 7. It must, in the event of a train breaking into two or more parts, be capable of immediate automatic application to every vehicle, under all conditions. 8. It must be simple in its construction and in its mode of working, and not be more liable to derangement in any of its parts than any other portion of the mechanism on the train. 9. The duties it is called upon to perform must be done by the apparatus itself, and not by the addition of any auxiliary contrivance called in to aid an appliance which cannot of itself fulfill the necessary conditions. 10. It should preferably be inexpensive for first establishment, and necessarily cheap in maintenance; for if the latter condition be not fulfilled, constant watching and frequent renewals would be required, and the eighth requirement named above would not be complied with.

470.




Continuous brakes may be divided into four varieties: 1. Those operating throughout the train by rods and chains and similar mechanical devices. 2. Those in which the mechanism is operated by electro-magnetism. 3. Those in which water is forced through pipes, which thus serves as a means of transmitting the power, or hydraulic pressure is otherwise applied. 4. Those in which the braking devices are operated either by compressed air or by air at normal pressure through the production of a vacuum. Prominent types of each variety will be considered:

1. Chain and Mechanical Brakes.—The operation of the *Creamer brake*, Fig. 470, may be described as follows: To the ordinary hand-wheel and brake-shaft (for winding up the brakes) is attached a drum, *A*, or loose pulley containing a strong spiral spring This spring is wound up by a reverse motion of the brake-shaft, to which is attached an arm and pawl, *G*, taking into a circle of ratchet teeth on the top of the drum *A*. When the spring is wound ready for use, it is held in check by a lever, *B*, from the extremity of which passes a branch line to the top of the car at *D*, and connecting about 3 feet forward to the bell-cord. The branch-line is attached to the

lever *B* by a ring in such a way that, when the lever is drawn up vertically, the ring disconnects. This is rendered necessary to insure the working of the brakes by the bell-cord, whether the train is extended on an up grade, or contracted on a down grade. The attachment of the branch line of each car, some 3 feet forward, enables the engineer to apply the brakes of all the cars simultaneously, by pulling the bell-cord, and at the same time it does not interfere with the bell-cord as a means of enabling the conductor to signalize the engineer. When the conductor pulls the bell-cord it rings the bell, and simply makes slack on the several branch-lines connected with the brake, but does not operate the brake. The conductor, brakeman, or even passengers, however, can, if an emergency arises in any part of the train, instantly close all the brakes, by pulling the bell-cord, or any accidental separation of the train produces the same effect, namely, bringing the retarding force on all the cars into instant action.

The *Heberlein Brake* is not a true continuous brake, though it may be fitted to every car in the train, the plan being, however, to divide the train into sections, including one brake-car in each, and the operator in this car can apply the brake to his own car, and to one or more others in connection with it. The brakes are applied to the wheels by a friction-pulley, which engages with a friction-wheel on one of the axles of the engine or of the brake-car. The revolution of this wheel winds up a flat link chain, and this pulling on a set of rods under the cars applies the blocks to the wheels. By pulling a cord, which extends through the cars, a detent is thrown out of gear, and the friction-pulley, which is hung on a weighted bell-crank lever, is suffered to fall into contact with the friction-wheel on the axle, and the brake is applied as soon as the train has run far enough to wind up the slack of the chain. The cord is kept taut, so that in case a car runs from the track, or becomes detached, a strain is brought upon the line, and the brakes are immediately applied.

The *Clark and Webb Chain-Brake* is about the same as the preceding, the brake being applied by the tightening of a chain which is attached to a drum beneath the van, this drum being so mounted that it can, when desired, be driven by bringing it into contact with a friction-wheel fixed on the van axle.

*Fay's Continuous Brake.*—Each carriage has a shaft passing along it from end to end, a screw on this shaft actuating the brake-levers. The shafts are coupled up between each pair of carriages by a square bar, of which one end carries a coupling-wheel; the other end slides in a socket forming part of the shaft beneath one of the carriages. The square coupling-bars thus transmit the rotary motion from one shaft to the other, while the sliding movement of the bar just mentioned allows for the play of the buffers.

*Becker's Continuous Friction Brake* is an ingenious invention, in which the momentum of the train is employed for the creation of the retarding power. Its principal part, the friction-gearing, consists of a horizontal axle, suspended by movable arms, *D*, Fig. 472, from the car frame. This axle carries a fixed sheave, *A*, Fig. 471, at each end, and on each sheave is a friction-ring *B*, fitted so loosely as to enable it to turn easily on the sheave. These rings are placed opposite the tires, and, according as they are intended to press against the tires or to grip the flanges of the wheels, are made cylin-

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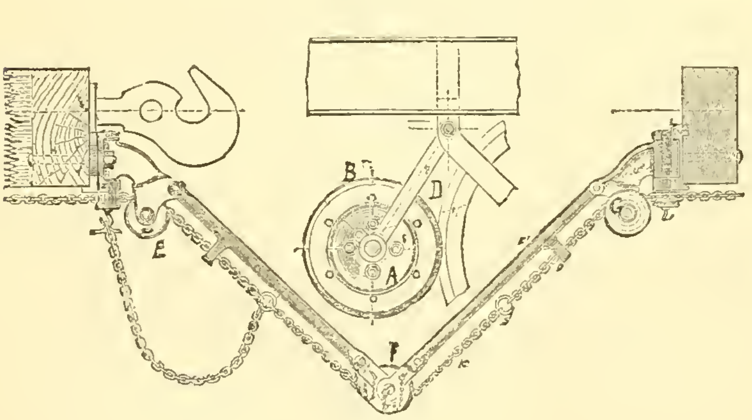

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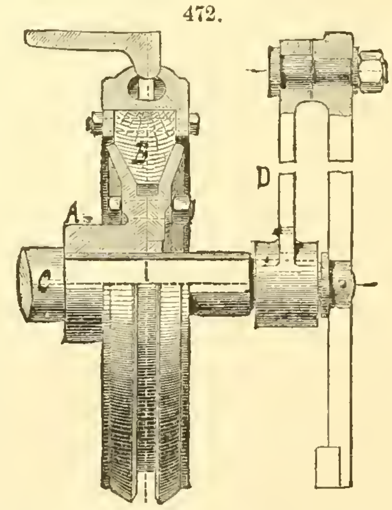

drical or with grooves. They may be brought into contact with the tires or lifted from them as desired. When in contact, the rings receive motion from the wheels with the same peripheral speed, and the friction between the rings and the sheaves winds up a chain fastened to their axle, *C*, Fig. 472. The latter, being connected in the usual way to the friction-blocks, presses them against the wheels. Since the winding up of the brake-chain is not effected directly by the revolving friction-ring, but by means of the axle and fixed sheave working within it, the axle can only be turned until the chain has been fully wound up, when it will remain still and be in no way affected by any further motion of the friction-ring, however long it may continue to revolve. The friction-ring does not come to a standstill until the wheel with which it is in contact ceases to move. By means of this peculiar combination of the ring between the driving-wheel and the mechanism which sets the brake in action, not only is the desired effect obtained in every case and for each special demand, but the usual concussions on the first application of the brake are, it is claimed, avoided, and the skidding of the wheels rendered impossible. The brake is instantly thrown out of gear when the friction-ring is withdrawn from the periphery of the wheel. The control or intermediate gear which serves to determine the position of the friction-ring with regard to the tire of the wheel, either by bringing it into contact with or removing it from the latter, consists of an axle fitted to the framework of the

carriage, with a winch-handle at each end, and carrying a fixed double-grooved sheave, round which in opposite directions are wound chains, two of which connect with the friction-axle. If the transmission-chain be tightened, a partial revolution of the sheave is effected; and by the other chains the friction-gear is either brought into contact with or withdrawn from the wheel. In whatever direction the chain may be pulled, the action is always the same. It being important to have all the brakes in the train begin to act simultaneously, it was necessary to provide a compensation for changes in the length of the train; and this was accomplished by carrying the chain from car to car, through three pulleys, *E, F, G*, two stationary and attached to each end of the coupled cars, and the third held at its centre by two rods, the other end of the rods being pivoted in the centres of the other pulleys. The three pulleys represent thus the corners of a triangle with a flexible base (which would represent here the play between the cars) and height, and with two sides of a constant length. Around these sides the chain is carried from car to car, and its length is thus constant, and unaffected by any slack in the train. An apparatus on the tender, which can be also placed at any point of the train, or in several places, pulls on the chain by means of a crank or a hand-wheel, and puts the brakes on. To this end, after the train has been made up and the ordinary coupling fastened, the whole of the friction-sheaves, as well as the side winches, are let down until the friction-rings are brought into contact with the tires; the transmission-couplings are then fastened between the carriages by being brought together and bolted, and the transmission completed by passing the end of one chain over the centre pulley and fastening it in the ring on the chain of the next wagon. The surplus piece is then hung up and fastened as a reserve chain, as shown in Fig. 471. The junction of the chains is chosen at such a point, that with the maximum motion of the chain, either by tightening up or slacking out, it cannot pass over either of the pulleys. The tension thus kept on the transmission-chain while running is so uniform, and so entirely independent of the position of the carriages, that an application or taking off of the brakes is said to be instantaneous throughout the length of the train. If, for instance, the disk-handle of the brake-spindle on the tender be suitably operated, the whole transmission-chain will be raised or tightened up, and each particular friction-sheave removed from the tires. In the event of the train breaking in two or more parts, the separated parts would immediately be automatically acted on by the brake. Another advantage which this brake possesses over many other continuous brakes is, that its action begins without any shock, but gradually, although its maximum power is developed in a very short time. The inventor claims that by this brake any train at the highest speed can be brought to a standstill in all weathers in 1,476 feet. For results of trials, see *Engineer*, xlv., 76.

2. Electro-Magnetic Brakes.—*Achard's Brake* (*French*).—Each carriage of the train is supplied with a galvanic battery of six Daniell cells. These batteries are connected with each other, and with the engine foot-plate, by means of four insulated wires passing through the whole length of the train. By means of these wires two distinct currents may be created, either of which may be closed or broken by altering the position of a handle placed before the engine-driver. In the frame of each car is a transverse arbor above the forward axle, upon one end of which is fixed a strong ratchet-wheel. A lever, pivoted at a point behind the axle and lying thereon (when the apparatus is working) carries at its extremity a click, which falls into the teeth of the ratchet. The axle has a cam at the point where the lever crosses it, and this cam, at every revolution of the wheel, lifts the lever sufficiently to advance the ratchet one tooth. On the ratchet arbor is a powerful electro-magnet, and also on the arbor are two loose barrels carrying armatures; when the magnet is excited these armatures are fixed by its attraction, so that the barrels then turn with the magnet. To each barrel is attached a chain, which is thus wound upon the barrel, and through which the levers are operated to apply the brakes to the wheels.

3. Hydraulic Brakes.—*Barker's Hydraulic Brake* (*English*) comprises a pump, a cistern, and an accumulator for collecting and storing the power, a regulator and an apparatus for applying that power in retarding the speed of the train. The pump, which is double-acting, is worked by mechanism in connection with a friction-wheel, which is brought in contact with one of the car-wheels. From the cistern, which holds about 25 gallons, the water is pumped into an accumulator, the piston of which is forced up against the resistance of spiral springs. In order to render the action of the accumulator as nearly constant as possible under the constantly varying conditions of train-length, there is an ingenious automatic arrangement whereby the pressure is always maintained in the accumulator sufficiently high for any emergency.

The arrangement for distributing and utilizing the hydraulic power for the purpose of retarding the train consists, first, of a pipe 1¼ inch in diameter fixed under each carriage. The main pipe is made continuous from a regulating apparatus (which controls the passage of water from the accumulator) throughout the whole length of the train, by means of flexible tubing connected to the pipes by ordinary union-joints. From the main pipe are lateral branches leading to hydraulic cylinders. These are each 4 inches in diameter, and one is provided for every wheel to which it is desired to apply brake-power. Each wheel has two brake blocks, and the ram of the cylinder is fixed to the block nearest to it, the cylinder itself being connected by a pair of rods to the block, on the opposite side of the wheel. On the water being admitted to the cylinder, or rather pressure being put upon the water already contained in the cylinder, both blocks are forced on the wheel. In order to withdraw the blocks upon the removal of the water-pressure from the ram, a spiral spring is placed inside each cylinder. Upon the ram being relieved from pressure, the tension of the spring forces a portion of the water back into the cistern for further use, and at the same time clears the brake-blocks from the wheels. An ingenious automatic contrivance preserves a given amount of clearance, and causes the wear of the blocks to be followed up. The apparatus may be worked from the locomotive as well as from any car.

*The McBride Hydraulic Brake* (*American*).—In this apparatus the power is derived directly from the steam-pressure against the water in the boiler, this pressure being communicated to a pipe

filled with water and running from the tender underneath all the cars of the train. The water is first conveyed from the tender-tank to a 3-way cock, which is placed on the locomotive, where it is always under the control of the engineer. Another pipe leads from the cock to the boiler below the water-line; a third pipe leads from the same cock and runs under the cars, the connections between the cars being provided for by means of hose couplings with self-closing valves. Under each car is a cast-iron cylinder with a piston, the rod of which is connected to the brake-levers. The pipe at each end of the train has an air-cock, to allow the air to escape while the pipe is being filled with water. As long as the train is running, the communication from the tender to the pipe running under the cars is kept open, thus keeping the pipes and brake-cylinders constantly full of water. The train can be stopped by a turn of the lever, which operates the 3-way cock and closes the communication between the tender and pipe under the cars. This cock is so constructed that the communication between the water-tank and boiler can be shut off so as to prevent the pressure from acting on the water in the tank. To relieve the pressure and to take off the brake, the engineer simply turns the lever back to its original position, and the brakes are instantly off, the surplus water being forced back into the water-tank by the recoil spring on the brake-levers.

*The Henderson Hydraulic Brake* (*American*), Fig. 473.—Between the wheels of each truck is placed a cylindrical vessel of cast-iron, the ends of which are formed of two dish-shaped flexible diaphragms of India-rubber, secured to the drum and making an air-tight joint at the periphery by flanges bolting thereto. Two rams, working in opposite directions, are fitted against and into the hollow part of the diaphragms. Their outer ends are attached by rectangular flanges and bolts

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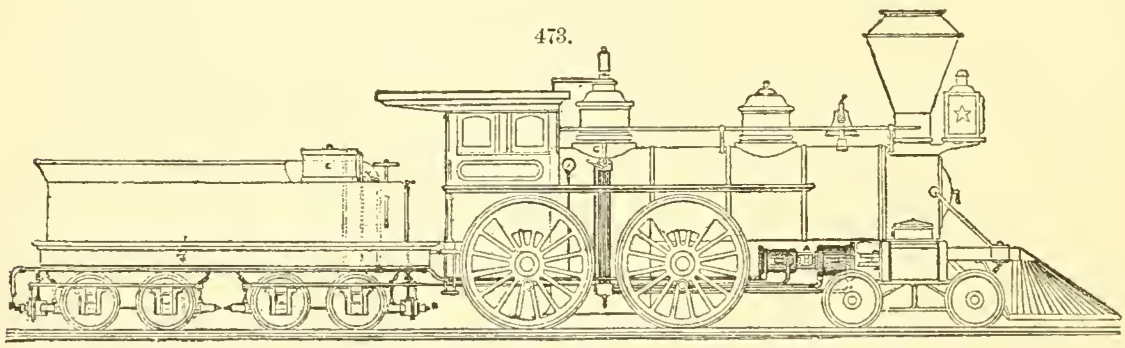

to the brake-beams, carrying the brake-shoes. When pressure comes between the diaphragms it simply forces them apart, projecting the rams, which act immediately on the brakes; and, when the pressure is relieved, the atmosphere reacts on the area of the rams and forces them back, assisted by the tendency of the diaphragms themselves to recover their normal position. The power is transmitted from an hydraulic press operated by a double-acting steam-cylinder, the valve of which is worked by the engineer.

In the annexed engraving, Fig. 473, the brake-shoes are arranged outside the wheels, and hence one of the diaphragms and rams is dispensed with. *A* is the double-acting pressure-engine, *C* the valve thereof, *B B* the pressure-boxes, and *E* is an especial water-tank for use where the water from the boiler is not employed.

*Clark's Hydraulic Brake* (*English*).—The brakes are actuated by one cylinder under each carriage. The water under pressure is supplied as follows: Under the foot-plate of the engine is a vertical cylinder, having an horizontal cylinder connected to it near its upper end. To the vertical cylinder is fitted a deep piston, and to the horizontal cylinder a plunger, which actuates the brakes on the engine-wheels. The cylinders between the piston and plunger are filled with water, a pipe leading from the tender-tank, and fitted with a valve opening inward, making up losses by leakage. To apply the brakes steam is admitted under the piston in the vertical cylinder; and this piston, rising, forces outward the plunger already mentioned, and also furnishes a supply of water under pressure to the pipes, and thus applies the brakes.

4. Air-Brakes.—These may be subdivided into those operated through a vacuum and those operated by compressed air.

*Vacuum.—The Sanders Vacuum-Brake* (*English*) differs materially from others of its class, inasmuch as, instead of a vacuum being employed to apply the brake, it is made use of to retain the brake-blocks out of contact with the wheels. In other words, the brakes in their normal condition are "on," and the blocks are withdrawn from the wheels by the action of the atmospheric pressure exerted upon diaphragms, from the other side of which the air has been partially exhausted. The means by which this system is carried out consists of an exhausted pipe extending the entire length of the train, connected between the carriages by flexible pipes and couplings, and an exhausted drum under each carriage, by which the brakes are released when the train is in motion. The pipe and apparatus are exhausted while the train is standing by means of a steam ejector, through which the steam, which is now used as a "blower," passes before entering the chimney of the locomotive. When the vacuum is once created, very little power is required to maintain it; and when the train is in motion the requisite exhaustive action is effected by a small pump worked from one of the piston cross-heads of the engine.

*Smith's Vacuum-Brake.*—In this device the blocks are applied to one side of each wheel by the collapsing of India-rubber cylindrical bags, which are supported by internal rings, so that when the air is exhausted from them they collapse endwise, and thus act on the brake-levers. Throughout the train there extend two lines of pipe, the various bags being connected to one line while the other extends right through to the rear, where it is connected to the first-mentioned line by the coupling-up of the

rear hose-pipes on the last vehicle. The exhaustion of the air from the pipes is effected partly by a couple of steam ejectors on the engine, and partly by exhausters fixed one in each brake-van, and driven by a wire rope, which passes over a grooved pulley, cast in one piece with a friction-pulley, which can be brought into contact with another friction-pulley fixed on the van-axle. The movable friction-pulley is forced against the axle-pulley by means of a spring, but, when the train is running, the two pulleys are held apart by a kind of trigger arrangement, which is connected by a cord with the collapsing bag with which each car is fitted. The effect of this arrangement is that, immediately the bag begins to collapse from the ejector of the engine being set at work, it releases the trigger, and thus brings the friction-wheels into contact, and causes the exhauster to be driven.

*The Westinghouse Vacuum-Brake.*—In this system the vacuum is produced by an ejector which is represented in Fig. 474. Steam is admitted into this through the pipe $A$, and escapes through the annular opening $b$ $b$ and the central jet $F$ $F$ $G$, which creates an induced current up the pipe $C$ $C$. This communicates with the two pipes $D$ $D$, which are connected with the brake-pipes. Under each car are two India-rubber collapsible cylinders, similar to the bellows of an accordion. When a vacuum is produced inside of these cylinders, the atmospheric pressure is exerted on the outside to compress them. Iron rings are inserted in the inside so as to prevent the cylinders from collapsing sideways, so that the atmospheric pressure is exerted on the heads. One of the heads is bolted fast to the car, and the other is attached to the brake-levers, so that whatever pressure is exerted on the movable head is communicated to the brake-levers, thus applying the brakes. Where the collapsing bag as above described is not used, a cylinder is placed vertically, and at each side of it there is hung a lever, having jointed to it, at an intermediate point, a toggle-lever. The two toggle-levers have curved abutting surfaces, and each is traversed by a pin, which rests upon a cross-head attached to the piston-rod. The effect is that, as the piston rises on the air being exhausted from the cylinder, the toggle-levers are drawn upward and the hanging levers are forced outward. To the lower ends of the hanging levers are coupled the thrust-rods leading to the brake-blocks, and thus the latter are applied to the wheels by the upward movement of the piston.

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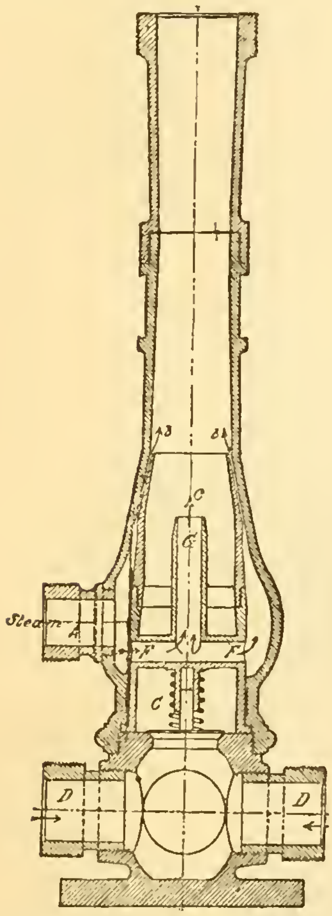


*Compressed-Air Brakes.*—*The Westinghouse Automatic Brake.*—The Westinghouse *atmospheric* brake, in its original form, consisted of an air-pump operated by a steam cylinder on the engine. This pump forced air of any required density into a reservoir usually placed underneath the foot-board of the engine. Each car was provided with a cylinder and piston underneath the body. The piston-rod was connected with the brake-levers, and the air-reservoir communicated with the cylinders by pipes, which were connected together by flexible hose between the cars. When it was desired to apply the brakes, the communication between the reservoir and the brake-cylinders was opened by turning a cock so that the supply of compressed air stored up in the former could flow into the cylinder, and would then force out the pistons and thus apply the brakes. With this apparatus it was found, however, that some appreciable time was required to allow a sufficient quantity of air to flow through the pipes to fill the brake-cylinders under each of the cars. The time consumed, of course, increased with the number of cars, because not only was the *length* of the pipes through which the compressed air had to flow increased, but the number of cylinders and, of course, the *quantity* of air were increased in like proportion.

There was also another difficulty encountered. In case of the breakage of a car-coupling in a train, which occasionally happens, the locomotive runner would sometimes apply the brakes to the portion of the train connected to the engine, and thus arrest its speed. As the connections of the air-pipes were separated by the breaking of the coupling, it was, of course, impossible for him to control the speed of the cars which had broken loose by means of the atmospheric brake. Accidents sometimes resulted in this way by the rear cars running into the front part of the train.

In the automatic brake the construction is simplified, and but one line of pipe is used. The compressing apparatus, consisting of a steam-cylinder $A$ and pump $B$, Fig. 475, is bolted to the boiler or frame, and steam for its operation is taken directly from the boiler through the pipe $a$, the amount being regulated by the throttle, while the exhaust is led by the pipe $a'$ to the smoke-stack. The air enters the pump $B$ by the pipe $b$, and is forced through the pipe into the reservoir $C$, Fig. 476. The pipe $c$ leads to one opening of the three-way cock $D$, and, from a second opening, is extended beneath the foot-plate, and, by a flexible hose, connected to the pipe on the tender. A differential piston-valve movement is used, in which the difference in area between the two ends is such that, when steam is admitted between them, the tendency of the valve is to move upward, which gives a downward stroke to the main piston. When the main piston reaches the bottom of its stroke it operates upon the reversing valve-rod, causing the valve $E$ to uncover a port by which steam is admitted above the piston $F$, which, by excess of pressure, causes the main valve to descend, exhausting from the upper part of the steam-cylinder, and admitting steam below the main piston. As the main piston completes its upward stroke, the valve $E$ is again moved so as to exhaust the steam from the reversing cylinder, whereby the reversing piston is moved upward, together with the main valve, by the difference of pressure between the two valve-pistons.

Figs. 477 and 478 show the application of the automatic brake to an ordinary 8-wheeled car. Fig. 477 is an inverted plan, and Fig. 478 an end-view.

The brake-cylinder *A*, Fig. 477, is bolted to a plank, and securely fastened to the longitudinal timbers underneath the car. The piston of this cylinder has a cross-head, *a*, having an arm, *b*, to which the spring releasing lever *c* is connected. To this cross-head *a* is attached one end of the lever *d*, the opposite end of which is connected to the brake-rod *e*. On the end or head of the cylinder *A*, opposite the cross-head *a*, is a bracket, *y*, which acts as a fulcrum for one end of the lever *f*, the other end of which is also pivoted to another brake-rod; the levers *d* and *f* are connected by a tie-

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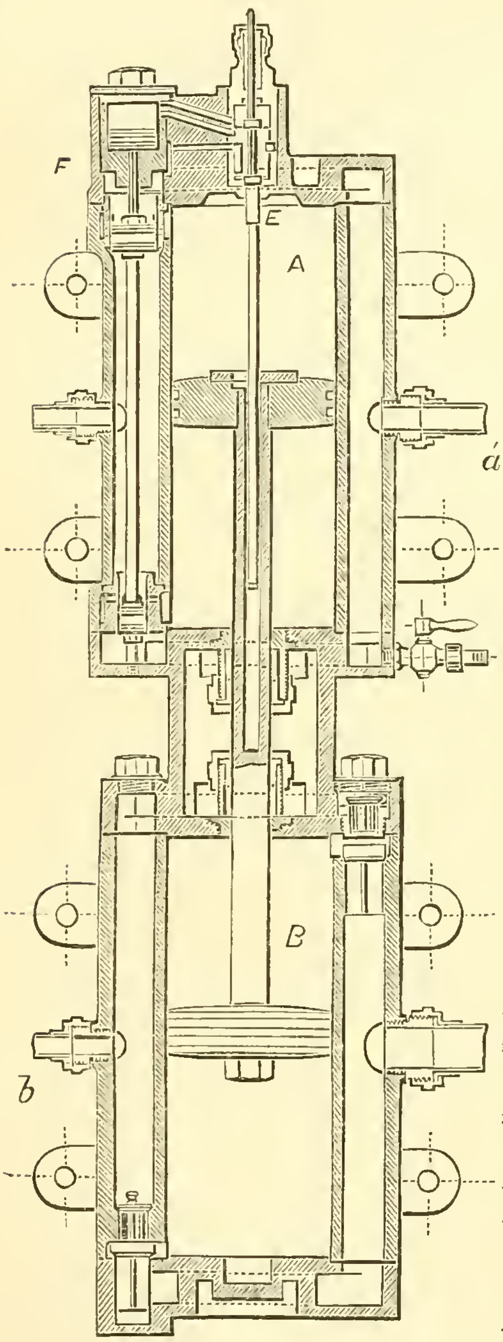


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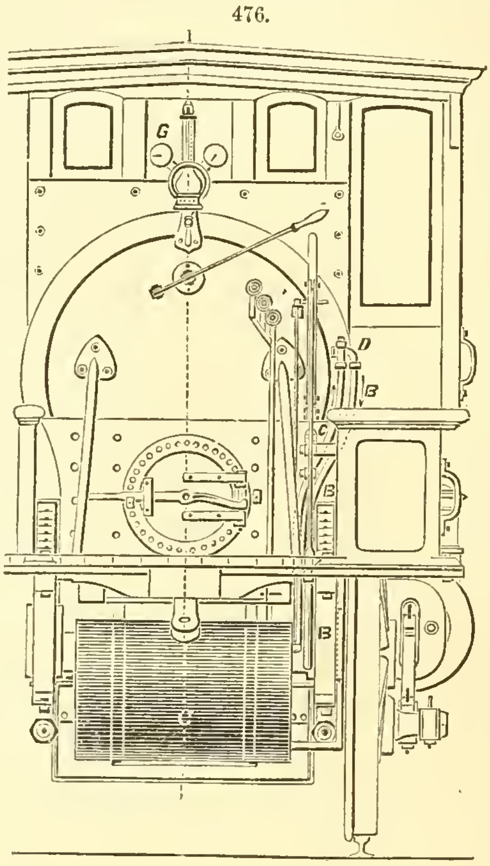
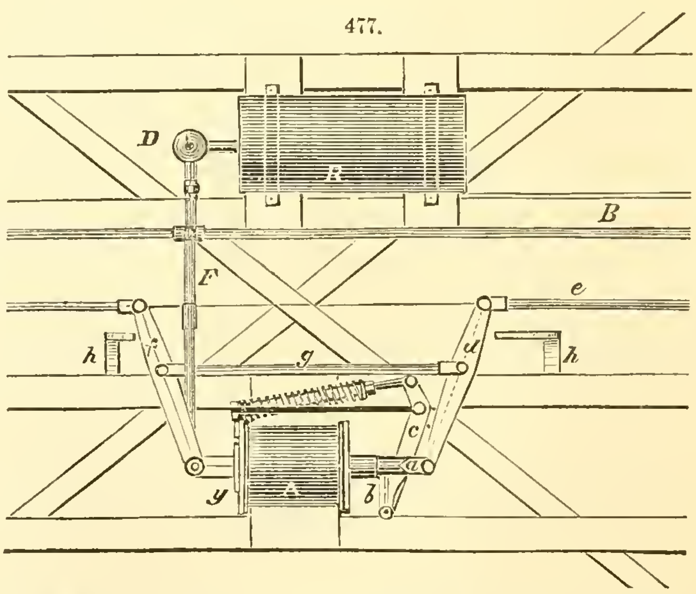


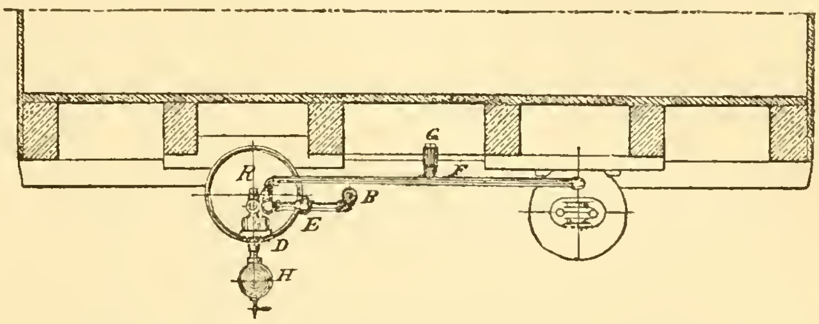

477.



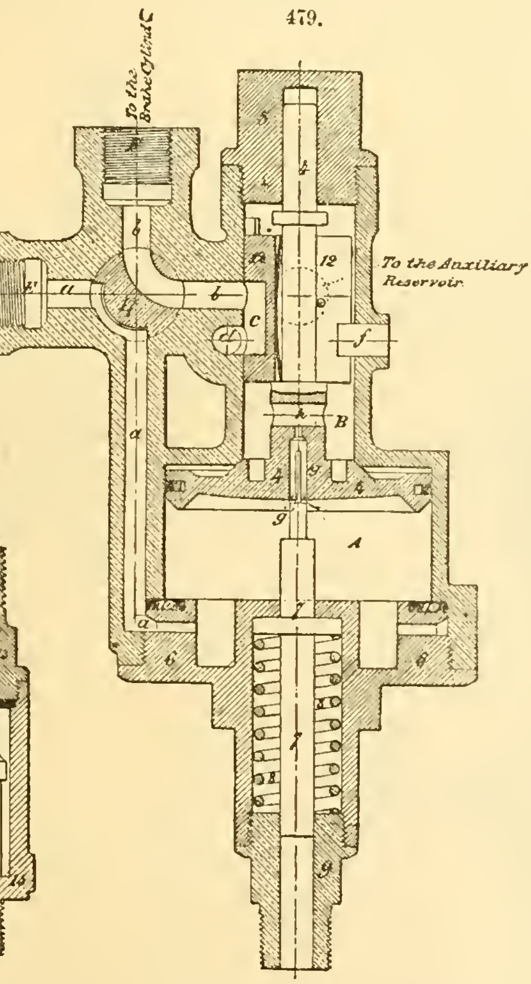

rod, *g*. These levers are so arranged that if the piston be thrust forward, carrying the cross-head *a*, the two rods *e e* will approach each other, and thus apply the brakes. The levers *d* and *f* are held in an horizontal position by the bracket *h* (a portion of which is represented as broken away in Fig. 477), made of light wrought-iron, and attached to the frame of the car. The brake-pipe *B* is arranged as near the centre of the car transversely as is convenient, and the stopcocks are near each end of the car. The auxiliary reservoir *R* is also attached by iron straps to the bottom of the car, and into one end is screwed a pipe, connected to which is the triple valve *D*. As the action of the brake is to a very great extent dependent upon the working of the triple and leakage valves, in order to understand how the pressure of the air is controlled, it is necessary first to understand clearly the action of this ingenious and beautiful contrivance. Fig. 479 represents a section of the triple valve, and Fig. 480 a section of the leakage valve.

The triple valve has a case, or body, with three connections for half-inch gas-pipe, the connection from the main pipe being through the port *E*; a second pipe-connection from the port *F* leads to the brake-cylinder, while the remaining port, shown in dotted lines back of the valve 12, is connected to the auxiliary reservoir. This case contains the body of the four-way cock, 17, and valve-chamber, *B*, and has also a piston-chamber, *A*, fitted with a piston and stem, 4, which is kept central with the bore of the two chambers by the end of the stem sliding in the hollow cap 5, screwed into the upper end of the case. A slide-valve, 12, is fitted loosely between a shoulder and collar of the stem of the piston, and moves with it. In the chamber *B* under this slide-valve are two ports or passages, *b* and *d*; the first, passing through the plug of the four-way cock, 17, connects with the port *F*, and thence to the brake-cylinder. The port *d* communicates directly with the atmosphere, and with a cavity, *c*, formed in the valve 12; and the port *b* constitutes a discharge-passage for the release of the compressed air for the brake-cylinder after the application of the brakes. The piston 4, packed with a ring, 11, has a central port, *g*, leading into the opening *h* through its stem, which is the only passage for air between the chambers *A* and *B*. Into the lower end of the case is screwed the cap 6, with a rubber packing-ring, 10, interposed between it and the chamber *A*. This cap has a chamber containing a stem, 7, with a collar, between which and the second cap, 9, is the spring 8, pressing the stem and collar with considerable force against the upper end of the chamber containing them. This stem, 7, passes a short distance into the chamber *A*, where it is turned down at *g*, so that the port *g* in the piston may slide over it and against the shoulder thus formed. A small needle, long enough to pass into the passage *h*, is fitted in the end of the stem which enters the port *g*, and serves to keep the passage free from dirt.

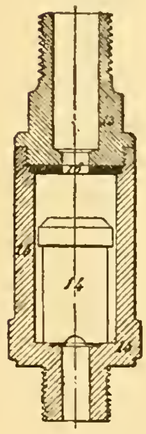
478.



479.




480.



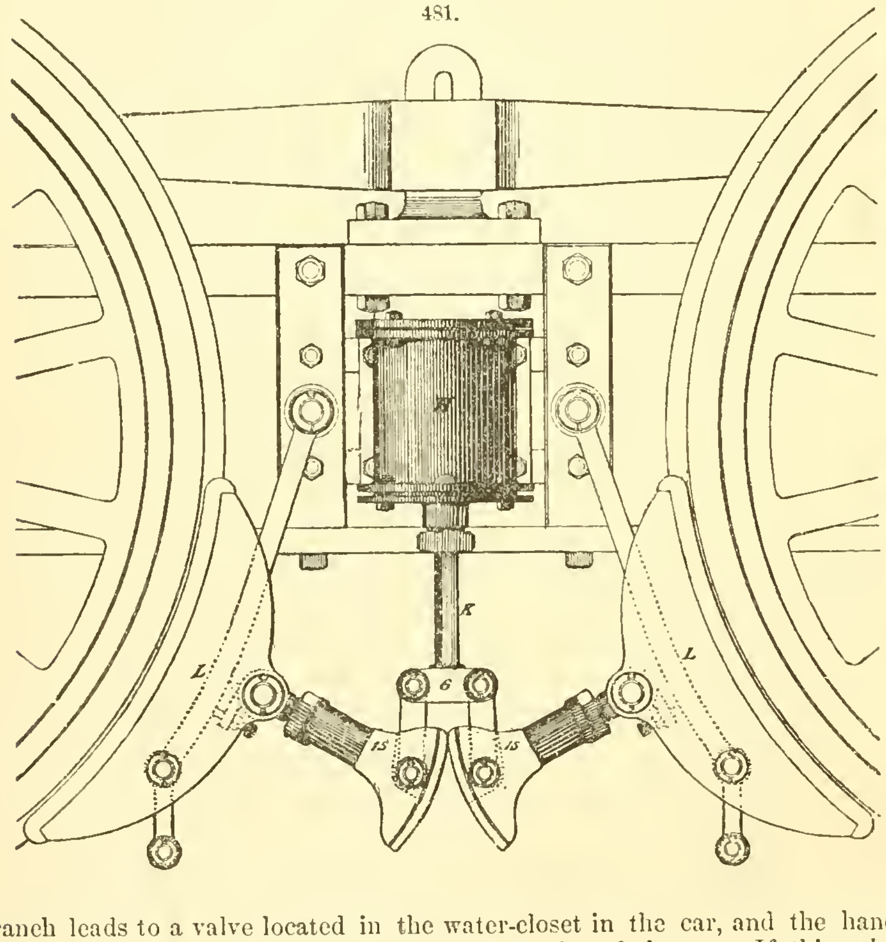
From the main brake-pipe, the air enters by the port *E*, and then, by the passage *a* through a suitable opening in the plug of the four-way cock 17, passes on through holes drilled in the cap 6 into the bottom of the chamber *A*, where, acting on the piston 4, it forces it with the slide-valve 12 into the position shown, opening the port *g* at *g'*, whereby the chamber *B* and auxiliary reservoir connected therewith are charged to the same pressure, this pressure being maintained throughout the train in all of the reservoirs and main brake-pipe. To fully apply the brakes, air is discharged from the main pipe, and consequently from the chamber *A*, when, by excess of pressure in the chamber *B*, the piston 4 is forced down, closing the port *g*, and forcing the stem 7 with its spring so as to permit the piston to seat itself on the rubber packing-ring 10; at the same time the valve 12 is moved, so as to uncover the port *b*, establishing communication from the chamber *B*, and consequently with the auxiliary reservoir to the brake-cylinder. To release the brake, air is again admitted to the main pipe and chamber *A*, causing by excess of pressure the piston 4 with valve 12 to assume the position shown in the drawing, whereby the ports *b* and *d* are brought in communication through the cavity *c*; at the same time the port *g* is opened for recharging the reservoir. To apply the brake lightly, a slight reduction of pressure is made in the brake-pin and chamber *A*, which causes the piston to move so as to uncover the port *b*, applying the brakes and reducing the pressure in the chamber *B*. As soon as the pressure is reduced so that it about equals that in the chamber *A*, the spring 8, acting against the collar of the stem 7 and piston 4, moves the valve far enough to close the port *b* without releasing the brakes. The force admitted to the brake-cylinder will depend altogether upon the reduction of pressure in the main pipe and chamber *A*, such reduction being entirely under control.

To prevent the application of the brakes after the engine is disconnected from the train by such reduction of pressure in the brake-pipes as may result from leakage, a small valve, the construction of which is clearly shown in Fig. 480, is inserted in the pipe between the port *F* and the brake-cylinder. This valve consists of a case, 15, with a cap, 13, having a rubber face, 16, and within the chamber of this case a valve, 14, which is acted upon by air-pressure entering the lower port. When the air enters this port slowly, as resulting from a leakage in the brake-pipe, or other slight reduction of pressure, the valve 14 remains in its position, such air passing around and to the atmosphere, without setting the brakes. When the brakes are being operated the valve is seated upward against the rubber face 16, preventing the escape of air. A drip-cup, *H*, is screwed on the cap 9 of the triple valve, and is provided with a cock. The plug 17 of the four-way cock, by a quarter turn, brings the ports *E* and *F* in connection, whereby the air passes directly from the brake-pipe to the brake-cylinder for the direct application of the brake, without charging any of the other parts. Both triple and leakage valves are arranged perpendicular in the pipes, as shown in the drawings.

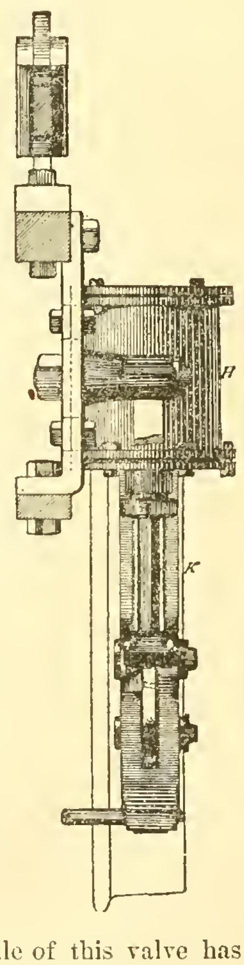
In the operation of the brakes, the couplings between the cars are connected in the usual manner, and the handles of all the cocks in the main brake-pipes are turned down so as to open them, excepting the one at the rear end of the train, which is turned so as to close the end of the pipe. When it is necessary to detach any portion of the train, the cocks must first be closed to prevent the escape of air and the application of the brakes.

Each reservoir, *R*, is provided with a small cock, which may be opened to release the brakes if they should be applied accidentally when the pipe is disconnected from the main reservoir. A

481.



482.



branch leads to a valve located in the water-closet in the car, and the handle of this valve has a cord-attachment which passes through the interior of the car. If this valve be opened by an employé or passenger in the train, the air will escape from the brake-pipe, and the brakes thus be applied to the whole train. The escape from this valve is led through the bottom of the car.

Figs. 481 and 482 represent the application of an atmospheric brake to the driving-wheels of a locomotive.

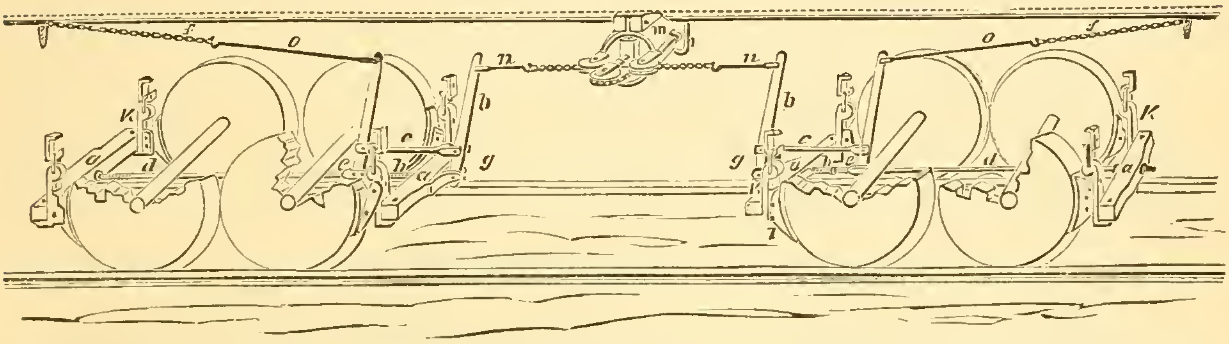
The brake is applied to the driving-wheels by means of a cylinder, *H*. The piston-rod *K* of the cylinder is connected by the cross-head 6 and two links with the cams 15, 15, which are attached to the brake-blocks *L L*. When compressed air is admitted underneath the piston in the cylinder *H*, it is obvious that its action on the cams 15, 15 will force the brake-blocks against the wheels.

*The Steel and McInnes Brake.*—This is applied under two different arrangements: that in which the cylinders are placed at the end of each carriage, in which case two brake cylinders are employed for each vehicle, and that in which the cylinder is placed at the centre of the carriage, in which case one cylinder is employed for each vehicle. The air compressing engine, mounted on the locomotive, consists of steam-engine and air-pumps. When the air is let out through the pipes from the reservoir, it enters the upper end of each cylinder, and escapes through a valve in each to the

receiver. Instantly, then, the pressure per square inch of area on both sides of the pistons is in equilibrio; but by virtue of the area of the upper side of the piston being greater than that of the under side, by a quantity represented by the area of a cross-section of the piston-rod, the pressure on the upper side preponderates by that amount, and this, together with the weight of the brake-gear, immediately causes the pistons to descend to the bottom of the cylinders, in which position the brakes are off. The air is kept constantly on, and to apply the brakes it is only necessary to open any one of the valves in the air-pipes, which can be done either by engineer, train-hand, or passenger, in either of which cases the air escapes from the upper sides of the pistons, and that on the under side not being able to escape—its pressure closing the valve by which it entered—immediately expanding, lifts the pistons and applies the brakes.

In the *Sickels Air-Brake* a spring is used to apply the brake and air-pressure to take it off. The apparatus is thus in principle similar to the Westinghouse, with the exception of the spring. The normal condition of the train is with all the brakes applied by the action of the springs. If the engineer wishes to start the train, he lets on the air-pressure, which detaches the spring and leaves the wheels free to move; the pressure is kept upon the pipes, and so long as this is done the brakes are kept released. To apply the brakes a portion of the whole of the condensed air is let off, and the action of the springs applies the brakes. If there be any defect in the connecting-pipe, the result cannot be serious, the only effect being that the engineer must stop and repair the pipe, and reëstablish the air-pressure before the wheels can run. By means of a cock in each car, leading to

483.




the air-pipe, the conductor can apply the brake from any car to the entire train; and this he can do as gradually or as suddenly as he pleases by regulating the discharge of air from the pipe.

*The Loughridge Air-Brake*, Fig. 483.—In this brake the air is compressed by a pump, which is worked by an eccentric on the front driving-axle. The air is pumped into a reservoir under the tender. It is necessary to run about half a mile to produce a pressure of 80 or 90 lbs. per square inch in the reservoir. When that pressure is reached the pump is stopped, but is always started again after a stop is made. The air is applied to the brakes by small cylinders under each of the cars, which are connected to the air-reservoir by half-inch pipes. These are coupled together between the cars by flexible hose. The annexed engraving represents the form of this brake employed in the trials referred to further on. The inventor, however, at the time of the preparation of this work, is engaged upon important improvements, calculated to add materially to the efficiency of the apparatus. He has devoted many years to the study of brakes, and he considers that "the indispensable requirements of a power-brake are an automatic governing power of the force, be the force what it may, capable of being graduated by the engineer or trainmen to deliver in pounds the pressure required; to utilize the maximum adhesion of the train in emergencies, and never slide wheels, the lighter degrees of force for other purposes to be regulated by the throttle or cock; to carry always a stored force in the reservoirs much greater than the pressure required in the pipes and cylinders; to insure several brakings before the air is reduced to a minimum pressure; to be able to brake the lighter cars in proportion to their relative weight with their fellow-cars in the train, and to be capable of graduating the force to the load."

Mr. Loughridge has devised an ingenious arrangement of cut-offs, on the diaphragms of which the air acts when forced from the reservoir to the pipes and cylinders. When the pressure in these diaphragms is equal to the required braking force, however uneven in the different cylinders, by reason of their respective cut-offs having been set by suitable gauges to suit differently weighted cars, the diaphragms give way and valves close, cutting off the air and preventing any increased pressure on the brake.

Tests of Brakes.—The following, explaining a simple rule for determining theoretically the retarding power of a good continuous brake as a means of comparison with actual reported results, is taken from the "Annual Report of the Railway Master-Mechanics' Association" for 1875:

"Let us suppose that a train consisting of an engine weighing 30 tons, with a tender weighing 20 tons and six cars weighing 20 tons each, in all 170 tons of 2,000 lbs., is running at a speed of 40 miles per hour on a straight and level track. It is required to know the distance in which said train can be brought to a state of rest, and the time consumed after shutting off steam and applying the brakes, which are assumed to be fitted to the tender and six cars. A speed of 40 miles per hour is equivalent to 58.7 feet per second, and by the law of gravitation a body projected vertically into the air, with an initial velocity of that amount, will ascend 53.5 feet before it is arrested by the force of gravity. Similarly a railway-train, moving on an horizontal track at the same speed, will be brought to a state of rest after shutting off steam, if a retarding force can be applied equal to its own weight. The resistance of the atmosphere is not taken into account in either case at pres-

*Results of Experiments on Continuous Brakes.*

| Class of Experiment. | Brake. | Total Weight of Train. Tons. | Cwt. | Lbs. | Percentage of Weight of Train resting on Wheels to which Brakes were fitted. | Speed of Train when Brakes were applied. | Time occupied in making Stop. Seconds. | Distance run after Application of Brakes. Feet. | State of Rails. | Resistance in Pounds per Ton, deduced from Distance run, after Application of Brakes ($Rd$). Lbs. | Resistance in Pounds per Ton, deduced from Time occupied in making Stop ($Rt$). Lbs. | Equivalent Distances which would have been run had Speed been 50 Miles per Hour when Brakes were applied. Feet. | Remarks. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| A. | Clark & Webb's | 241 | 9 | 1 | 16.5 | 49½ | 63 | 2,389 | Dry. | 82.77 | 87.22 | 2,437 | |
| " | Steel & McInnes's | 197 | 7 | 1 | 20.5 | 49½ | 86 | 3,205 | " | 61.70 | 63.89 | 3,270 | |
| " | Clark's hydraulic | 198 | 4 | 0 | 22.3 | 49½ | 83½ | 3,265 | Wet. | 60.56 | 65.80 | 3,331 | |
| " | Smith's vacuum | 257 | 12 | 2 | 20.2 | 49½ | 87 | 3,591 | " | 55.06 | 63.16 | 3,664 | |
| " | Westinghouse's vacuum | 204 | 3 | 0 | 20.9 | 49½ | 96 | 3,705 | " | 53.37 | 57.24 | 3,780 | |
| B. | Westinghouse's automatic | 203 | 4 | 0 | 81.1 | 56 | 22 | 1,020 | Dry. | 248.11 | 282.55 | 813 | |
| " | Clark's hydraulic | 198 | 4 | 0 | 58.7 | 54½ | 21 | 1,070 | " | 204.31 | 288.07 | 901 | |
| " | Fay's | 186 | 13 | 0 | 85. | 48½ | 24 | 1,016 | " | 186.83 | 224.30 | 1,080 | |
| " | Smith's vacuum | 195 | 12 | 0 | 87.3 | 47½ | 28 | 1,200 | " | 151.73 | 188.30 | 1,330 | |
| " | Clark & Webb's | 241 | 9 | 1 | 62.2 | 49½ | 31 | 1,384 | " | 142.87 | 177.25 | 1,412 | Train parted, owing to break of draw-hook while stopping. |
| " | Barker's hydraulic | 210 | 2 | 0 | 81.7 | 49½ | 34 | 1,628 | " | 121.46 | 161.60 | 1,661 | |
| " | Westinghouse's vacuum | 204 | 3 | 0 | 81.8 | 54½ | 46½ | 2,200 | " | 108.96 | 130.10 | 1,852 | |
| " | Steel & McInnes's | 197 | 7 | 1 | 81.8 | 49½ | 46¼ | 2,135 | " | 92.62 | 118.80 | 2,178 | |
| C. | Westinghouse's automatic | 203 | 4 | 0 | 94.3 | 52 | 19 | 913 | " | 230. | 304.49 | 844 | |
| " | Clark's hydraulic | 198 | 4 | 0 | 71.5 | 52 | 22¾ | 1,212 | " | 180.04 | 253.71 | 1,121 | |
| " | Fay's | 186 | 13 | 0 | 85. | 44½ | 27½ | 1,165 | Wet. | 134.05 | 179.62 | 1,471 | |
| " | Smith's vacuum | 262 | 6 | 2 | 95. | 49½ | 29 | 1,448 | Dry. | 136.6 | 189.5 | 1,477 | |
| " | Clark & Webb's | 241 | 9 | 1 | 51.7 | 47½ | 29 | 1,337 | " | 136.2 | 181.8 | 1,481 | |
| " | Barker's hydraulic | 210 | 2 | 0 | 94.4 | 50 | 32 | 1,549 | " | 134.2 | 176. | 1,503 | |
| " | Westinghouse's vacuum | 204 | 3 | 0 | 94.5 | 52 | 34½ | 1,728 | Wet. | 126.3 | 166.3 | 1,598 | |
| " | Steel & McInnes's | 197 | 7 | 1 | 81.8 | 49½ | 34¼ | 1,603 | " | 123.6 | 160.4 | 1,636 | |
| D. | Westinghouse's automatic | 203 | 4 | 0 | 94.3 | 52 | 18 | 840 | Dry. | 259.8 | 320.6 | 777 | |
| " | Fay & Smith's vacuum on engine and tender | 203 | 12 | 1 | 94.2 | 57¼ | 28 | 1,400 | " | 188.9 | 227. | 1,007 | |
| " | Smith's vacuum | 257 | 12 | 2 | 87.3 | 45½ | 22 | 920 | " | 181.6 | 229.6 | 1,111 | Engine reversed. |
| " | Fay's | 186 | 13 | 0 | 85.2 | 45½ | 22 | 928 | Wet. | 180. | 229.6 | 1,121 | Engine reversed—brakes of rear section of train believed to have been slightly applied before signal. |
| " | Clark & Webb's | 241 | 0 | 1 | 51.7 | 46½ | 22¼ | 979 | Dry. | 178.2 | 232. | 1,132 | |
| " | Barker's hydraulic | 210 | 2 | 0 | 94.4 | 49½ | 25 | 1,116 | " | 177.4 | 219.8 | 1,139 | |
| " | Steel & McInnes's | 197 | 7 | 1 | 81.8 | 49½ | 24 | 1,135 | " | 174.2 | 228.9 | 1,158 | |
| E. | Clark & Webb's | 241 | 9 | 1 | 58.7 | 50¾ | 24¾ | 1,096 | " | 189.7 | 227.6 | 1,064 | Engine reversed. |
| " | Steel & McInnes's | 197 | 7 | 1 | 81.8 | 46½ | 23 | 970 | Wet. | 179.9 | 224.4 | 1,122 | " " |
| " | Fay's | 186 | 13 | 0 | 85.2 | 45½ | 27 | 1,095 | Dry. | 152.6 | 187.1 | 1,322 | |
| " | Clark's hydraulic | 198 | 4 | 0 | 71.5 | 50¾ | 27 | 1,429 | " | 145.5 | 208.61 | 1,387 | |
| " | Westinghouse's vacuum | 204 | 3 | 0 | 94.5 | 49½ | 32 | 1,517 | Wet. | 130.4 | 171.7 | 1,548 | |
| F. | Westinghouse's automatic | 203 | 4 | 0 | 94.3 | 54½ | 20 | 930 | Dry | 257.7 | 302.5 | 783 | |
| " | Clark & Webb's | 241 | 9 | 1 | 49.3 | 39½ | 15 | 600 | " | 209.9 | 292.3 | 961 | Tender-brake not used. |
| " | Clark's hydraulic | 198 | 4 | 0 | 45.7 | 49½ | 28½ | 1,315 | " | 119.4 | 192.8 | 1,342 | " " " |
| " | Smith's vacuum | 257 | 12 | 2 | 75.0 | 42¾ | 23¼ | 1,088 | " | 135.6 | 204.1 | 1,488 | " " " |
| " | Fay's | 203 | 12 | 1 | 67.2 | 42¾ | 31 | 1,200 | " | 122.9 | 153.2 | 1,642 | Engine and tender brake not used. |
| G. | Westinghouse's automatic | 203 | 4 | 0 | 24.9 | 43½ | 69 | 2,278 | Wet. | 67.04 | 69.98 | 3,010 | |
| " | Clark & Webb's | 241 | 9 | 1 | 9.5 | 43½ | 94 | 3,299 | " | 46.29 | 51.37 | 4,359 | Engine reversed. |
| H. | Westinghouse's automatic | 111 | 15 | 0 | 100. | 53¼ | 16½ | 869 | Dry. | 263.3 | 358.2 | 766 | |
| " | Fay's | 136 | 17 | 0 | 100. | 42 | 25 | 1,007 | " | 141.4 | 186.5 | 1,427 | |
| " | Steel & McInnes's | 108 | 0 | 0 | 87. | 45½ | 28¼ | 1,320 | " | 126.6 | 178.8 | 1,594 | Hand-brakes in vans not used. |

ent. Now, the retarding forces available for stopping a train are the friction of the brake-shoes upon the wheels, the axle-friction, the rolling friction of the wheels upon the track, and the resistance of the atmosphere. The brake-friction bears a certain proportion to the pressure applied, and varies somewhat with the condition of the weather, but one-sixth of the pressure applied may be considered as a fair average allowance. The pressure upon the brakes is limited by the weight on the wheels fitted with brakes, and the weight on the wheels must always exceed the sum of the brake-pressure and axle and rolling friction to prevent sliding of the wheels. If we allow one ton for axle and wheel friction, to be on the safe side (it is actually less than half that amount), it will leave 139 tons available for brake-pressure, and one-sixth of this, $23\frac{1}{6}$ tons, or 46,333 lbs., will be the brake resistance. To this we must add the axle and rolling friction, and the resistance of the atmosphere, which, at the speed indicated, may be set down in the aggregate at 14 lbs. per ton of train, or 2,380 lbs., and the total resistance will then be 48,713 lbs., or one-seventh of the weight of the train. If, as before shown, a train will run $53\frac{1}{2}$ feet in 1.82 second, if the retarding force is equal to its own weight, it will run seven times that distance, or 374 feet if the retarding force is one-seventh of that amount, and will consume about 13 seconds of time. But this calculation is based on the assumption that the full brake-pressure is applied at the instant of shutting off, which is never the case in practice. With the original Westinghouse brake, three or four seconds are usually consumed in getting full brake-pressure upon a train of six cars, and it will be safe to assume that a distance of 160 feet will be passed over before the full effect of the brake can be exerted; and if this distance is added to that previously given, the total distance run after shutting off and applying the brake will be 534 feet, and the time required may be roughly stated as 16 seconds."

The table on page 226 shows the results of experiments on continuous brakes made on the Midland Railway, England, June, 1875. The tests marked A were on stopping trains by tender and van brakes only worked by hand. The trains were each started from a regular starting-point, and were given more than three miles to get up speed. The stops represent the best attainable, with ordinary tender and van brakes worked by hand, as the point at which the signal to apply brakes was known, and everything was in readiness. The data will serve as a certain basis of comparison from which the powers of the continuous brakes may be judged. Experiments B were on stopping trains by tender-brake, van-brakes, and continuous brakes applied by guard on flag or cord signal. Experiments C were on stopping trains by the application of engine, tender, and continuous brakes, no sand being used; the supposition being that the driver saw danger. Experiments D represent cases in which the driver does everything in his power to stop on receiving the signal. Engine, tender, and continuous brakes are applied, sand used, and the engine is reversed in cases where no engine-brake is fitted. Experiments E were on stopping trains on a signal given to the rear-guard, or at some intermediate point on the train, the driver being then signaled to apply brakes. The supposition is that danger is discovered by a rear-guard or passenger. Experiments F resemble the last in the fact that the signal to stop was given at the rear of the train, but differ in the driver taking no active part in the stopping, but merely shutting off steam on feeling that the brakes had been applied. Experiments G were on stopping trains by the use of the engine and tender brakes only, the engine being reversed when not fitted with a brake. Experiments H show the effect of parting-trains when running by a slip coupling, the continuous brake then being required to effectively control the two portions of the parted train.

In the table on page 226, which is condensed from that prepared by *Engineering*, vol. xix., experiments which failed wholly or partially are omitted. Descriptions of the brakes will be found elsewhere in this article.

A competitive trial occurred in January, 1877, between the Westinghouse vacuum and the Smith vacuum brakes on the North British Railway, with, among others, the following results: speed 55 miles per hour; number of seconds occupied in making stop: Smith, 28; Westinghouse, 21. Number of feet occupied in making stop: Smith, 1,375; Westinghouse, 910. At a speed of 30 miles per hour, the Westinghouse effected stop in 13 seconds and 328 feet. At 29.5 miles per hour, the Smith effected stop in 17.25 seconds and 480 feet. Total weight of train and load fitted with Smith brake, 173 tons; portion braked, 86.55 per cent. of total weight of train; total weight of train and load fitted with Westinghouse brake, 166 tons 10 cwt.; portion braked, 86.02 per cent. of total weight of train. For full table, see *Engineering*, vol. xxiii., No. 575.

*The Loughridge Air-Brake.*—This brake, constructed as shown in the engraving on a preceding page, was tested in February, 1876, on the Baltimore & Ohio Railroad, with the following result: total weight of train (10 coaches), 1,150.2240 tons; brakes applied to 92 out of 96 wheels; speed of train when brakes were applied, 42.61 miles per hour; time occupied in making stop, 16 seconds; distance run after application of brakes, 589 feet 8 inches. This was a test conducted under terms of contract with railroad named.

*The Henderson Hydraulic Brake.*—The following tests, reported in the *Car-Builder*, vol. vi., No. 3, were made in March, 1875, on the West Chester & Philadelphia Railroad. Train consisted of locomotive, one baggage and three passenger cars, weight not stated.

(1.) Train stopped while traveling at rate of 35 miles per hour, on down-grade 15 feet to mile, in 720 feet and 22 seconds. Steam-gauge pressure at dead stop, 104 lbs. Brake-gauge pressure, 95 lbs.

(2.) Train stopped on same grade, 30 miles per hour, in 22 seconds and 870 feet. Steam-gauge pressure, 105 lbs. Brake-gauge pressure, 90 lbs.

(3.) Train stopped on down-grade of over 30 feet, 30 miles per hour, in 31 seconds and 780 feet. Steam-gauge pressure, $92\frac{1}{2}$ lbs. Brake-gauge pressure, 90 lbs.

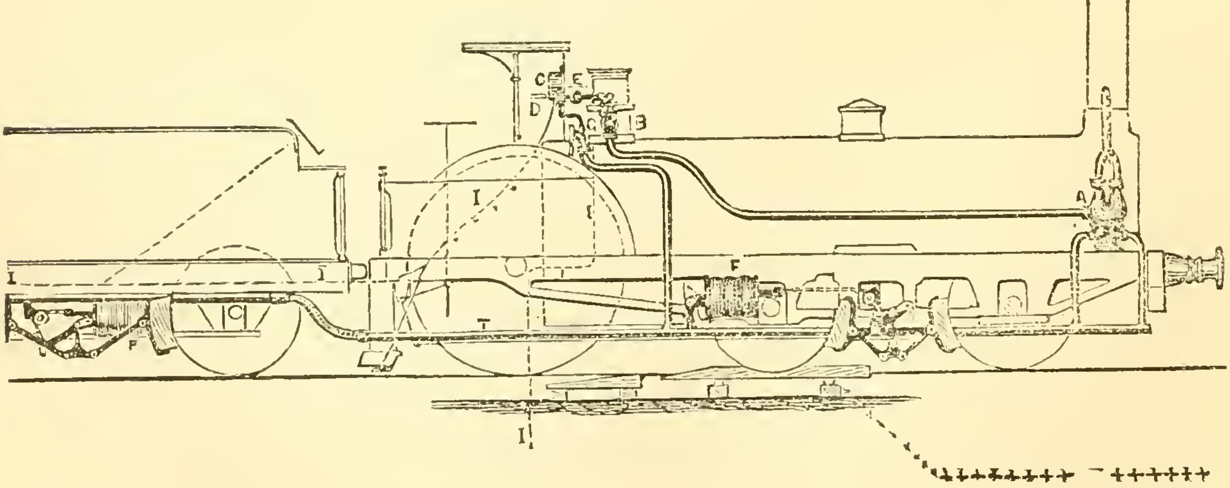
The following table shows the results of trials of the brakes named conducted in Germany in August, 1877:

*Table of Results, corrected for Speed, Friction of Train's Gravity, and Undue Brake-Block Pressure, Trains consisting of Engine braked on the Driving-Wheels, Tender braked on all Wheels, Four Carriages braked and Two unbraked.*

| Speed. Miles per Hour. | Pressure on Brake-Blocks in Percentage of Weight of Braked Portion of Train. | Distance from Point of applying Brake to Point at which the Momentum is reduced, as shown. | PERCENTAGE REDUCTION OF MOMENTUM. | | | |
|---|---|---|---|---|---|---|
| | | | Westinghouse. | Heberlein. | Steel. | Smith. |
| | | Feet. | | | | |
| 46.6 | 50 | 437 | 17.82 | 13.65 | 12.76 | 11.0 |
| | | | 20.63 | 17.65 | 15.53 | 14.99 |
| 55.9 | 50 | 656 | 25.74 | 19.96 | 21.93 | 20.14 |
| 46.6 | 87 | 656 | 59.43 | 89.57 | 40.85 | No results. |
| | | | 60.32 | 54.04 | 48.50 | No results. |
| 46.6 | 113 | 437 | 75.93 | Not tried. | 51.35 | Not tried. |
| | | | 60.24 | Not tried. | 44.37 | Not tried. |
| 46.6 | 50 | 984 | 54.70 | 39.13 | 35.13 | 41.89 |

Some very remarkable trials were made on the London, Brighton, and South Coast Railway, in England, conducted by Captain Douglas Galton and Mr. Westinghouse, in May and October, 1878. (See *Engineering*, xxv., 469; xxvi., 386 and 399.) Their object was to determine the coefficient of friction between the brake-blocks and the wheels, and between the wheels and the rails, at different velocities, both when the wheels are revolving and when skidded. For this purpose a special brake-van, fitted with the Westinghouse automatic brake, was built, and four ingenious self-recording dynamometers, designed and applied by Mr. Westinghouse, were used. Two of them recorded the retarding force which the friction to the brake-blocks exerts on the wheels; the third, the force with which the brake-blocks press against the wheels; and the fourth, the force required to drag the van. A self-recording speed-indicator, designed by the same gentleman, was used. Numerous diagrams were taken, showing the average tangential strain, the brake-block pressure, the speed of the pair of wheels to which brakes were applied, the speed of the train, and the traction on the draw-bar. The conclusions are as follows: 1. The pressure with which the brake-blocks are applied to the wheels should be as high as possible, short of the point which would cause the wheels to be skidded and slide on the rails. 2. The rotation of the wheel is arrested as soon as the friction between the brake-block and the wheel exceeds the adhesion between the wheel and the rail, and therefore the amount of pressure which should be applied to the wheel is a function of the weight which the wheels bring upon the rail. The value of this function varies with the adhesion; hence with a high adhesion a greater pressure can be applied, and a greater measure of retardation obtained, than with a low one. 3. In practice and as a question of safety it is of the greatest importance that, in the case of a train traveling at a high rate of speed, that speed should be reduced as rapidly as possible on the first application of the brakes. For instance, a brake which reduces the speed from 60 miles an hour to 20 miles an hour in say 6 seconds, has a great advantage as regards safety over a brake which would only reduce the speed from 60 miles to 40 miles an hour in the same time. 4. The friction produced by the pressure of the brake-block on the wheel is less as the speed of the train is greater; to produce the maximum retardation so far as speed is concerned, the pressure should thus be greatest on first application, and should be diminished as the speed decreases, in order to prevent the wheels from being skidded (or sliding on the rails) in making a stop. 5. The coefficient of friction decreases as the time increases during which the brakes are kept on; but this decrease is slower than the increase of the same coefficient due to the decrease of speed; it has, therefore, little influence in the case of quick stops. 6. The maximum pressure should be applied to the wheels as rapidly as possible, and uniformly in all parts of the train. 7. To prevent retardation from the dragging of the brake-blocks against the wheels when the brakes are not in use, care should be taken that the brake-blocks are kept well clear of the wheels (say half an inch) when in a state of inaction.

483 A.



*Automatic Application of Brakes by Electricity.*—An ingenious device has been adopted on the Northern Railway of France, by means of which brakes are applied automatically when the signals are against a train. The general principle involved is, that when the train passes a signal against

it, a brush of wire on the engine comes in contact with a raised wedge at the side of the rail, and closes a battery circuit. The moment this occurs the engine-whistle is sounded, and steam is turned on to the ejector and the brakes applied, without any action on the part of the driver or guard. This apparatus is illustrated in Fig. 483 A, which shows an engine and portion of a train fitted up. *A* is the double ejector producing the vacuum; *B*, balanced steam-valve; *C*, electro-automatic whistle; *D*, vacuum-gauge; *E*, counterweights under whose action the valve *B* opens, when the movement which opens the electro-automatic whistle *C* sets at liberty simultaneously the lever which carries the counterweights; *F*, vacuum-cylinders acted on by the ejectors and working the brake-levers; *I*, wires establishing the electric communication from one end of the train to the other, and conducting the current to the Hughes electro-magnet of the electro-automatic whistle; *T*, iron tubes forming air-conductors. By putting the commutators in the cars in contact with the earth, the electric current acts on the bells at the head and tail of the train, on the whistle *C*, and at the same moment on the lever with counterweight of the steam-valve *B*, which opens itself, and applies the vacuum-brake. The contact required to put the brake on can be made by causing the wire brush under the engine-step to come in contact with the wedge-piece shown between the rails. The dotted line shows the wire connected with the signal and battery.

BREAD AND BISCUIT MACHINERY. Good fermented bread is best made from the flour of wheat. The essential constituents of wheat flour are starch, also called farina or fecula, gluten, and a little albumen. According to Vogel, 100 parts of wheat flour contain of starch 68 parts, gluten 24, gummy sugar 5, and albumen .2; but these proportions vary with the goodness of the wheat.

The starch of wheat flour is very nutritive. Gluten is a mixture of vegetable fibrine, and a small quantity of a peculiar matter containing nitrogen, called *gliadine*, to which its adhesive properties are due. The small proportion of sugar in wheat flour enables it to ferment on being mixed with water, without the addition of yeast. Thus the dough of wheat flour, by spontaneous fermentation, becomes converted into leaven.

During the rising of the dough, carbonic acid is formed at every part, and is prevented from escaping by the gluten, which forms a kind of adhesive web. The formation of this gas causes the dough to swell in every direction, and the particles of starch to separate, in which condition the process is arrested by the heat of the oven, so that when the bread is cut open, it contains many cavities, each of which in the dough contained a globule of carbonic acid.

In the preparation of wheat for the manufacture of bread, the ground grain is usually separated into three parts, the *flour*, the *pollard*, and the *bran;* the flour forms, on an average, about three-fourths of the wheat ground. The white flour is pleasing both to the eye and taste, and there is a strong prejudice in favor of white bread; hence various methods of bleaching are resorted to, but it is doubtful if the whitest bread, even supposing it to be pure, is conducive to health and economy. By rejecting the *bran*, as we do when using only the finest flour for bread, we actually lose a large amount of nourishment of the most important kind. According to Liebig, the separation of bran from the flour *is rather injurious than useful to nutrition.* By using unbolted flour for bread the product is increased at least one-fifth. From the several varieties of flour obtained by *bolting*, three kinds or classes of bread are manufactured: 1. Wheaten bread, or *firsts*, which is made of the finest flour. 2. Household bread, or *seconds*, which is somewhat coarser. 3. Brown bread, *thirds*, which is made of flour of various degrees of coarseness. For making firsts, the flour is entirely separated from the bran or husks; in the other descriptions the bran is not entirely removed, but the coarse broad bran is separated from the coarsest flour.

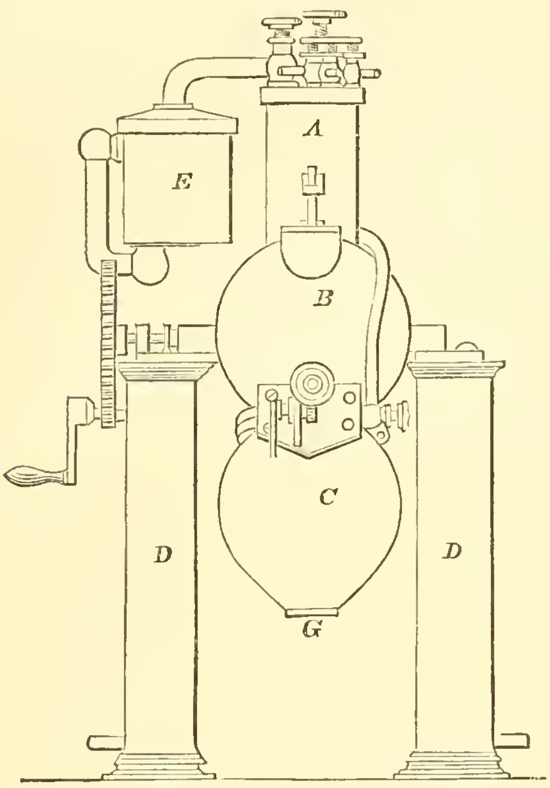
The baker generally takes a portion only of the water which he intends to employ in making the required quantity of dough, at a temperature of from 70° to 100°, and containing a portion of salt necessary to give the bread its proper flavor. Yeast is next mixed with the water, and then a portion of flour is added, always less than the quantity intended for the finished dough. The mixture is covered up and left in a warm situation. In about an hour this mixture, termed the *sponge*, thus set apart, begins to ferment. It swells out and heaves up, evidently in consequence of the generation of some internal elastic fluid, which, in this instance, is carbonic acid gas. When no longer capable of retaining the pent-up air, it bursts and subsides. After the second or third rising and dropping of the sponge, the baker interferes, otherwise the bread formed from this dough would be sour. At this period he therefore adds to the sponge the remaining portions of flour and water and salt, necessary to form the dough into the required consistence and size, and next incorporates all these materials with the sponge, by long and laborious kneading. The dough is left to itself for a few hours, during which time it continues in an active state of fermentation throughout its whole extent. After a second kneading, to distribute the gas within it as equally as possible throughout the whole mass, the dough is weighed out into portions requisite to form the kinds of bread desired. These loaves are once more set aside for an hour or two in a warm place, and the continued fermentation soon expands each mass to about double its former volume. They are now considered fit for the fire, and are finally baked into loaves, which, when they quit the oven, are nearly twice as large as when they entered it. The gas contained in the bread is expanded by the heat throughout every part of the loaf, and swells out its whole volume, giving it the piled vesicular structure. Thus a well-made and well-baked loaf is composed of an infinite number of cellules, each of which is filled with carbonic acid gas, and lined with, or composed of, a glutinous membrane; and it is this that communicates the light, elastic, porous texture to bread.

Various arrangements are in use for making bread by machinery. The usually laborious occupation of kneading and mixing the dough is now perfectly well performed by mechanical means, and automatic ovens receive the dough and return it baked to the basket. Thus large quantities of perfect bread are made expeditiously and at a low price.

*Aërated Bread.*—The apparatus devised by Dr. Dauglish for the manufacture of aërated bread is

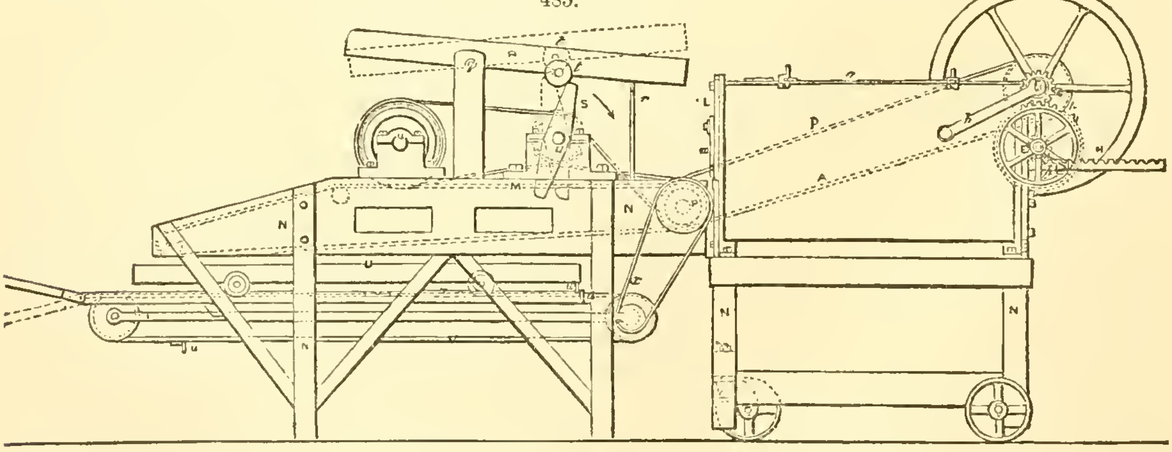
represented in Fig. 484. The water-chamber $A$ and mixer $B$ are cast in one piece, and communicate by an equilibrium-pipe and valved aperture; the water-chamber also communicates with a water-tank and with the gas-generating chamber $E$, through pipes whose discharge is controlled by cocks. The flour and salt are admitted to the water-chamber from the tank. When the gas attains a pressure of 100 lbs. per square inch, it is allowed to pass through the water, which, when thoroughly charged, is admitted to the mixing-chamber, where it is mingled with the flour and salt by revolving beaters. The receiver is secured to the mixing-chamber $B$, and communicates with it by a slide-valve so arranged that it cannot be choked by dough. The two vessels are also connected by an equilibrium-pipe, so that the pressure of gas may be equal in each, allowing the dough to fall into the mixing-chamber by its own gravity. From the receiver the dough is passed to the baking-pan, by means which allow of its being surrounded by air or gas under pressure, thus lessening the escape of the gas inclosed in the dough. The baking requires to be conducted in a peculiar manner. Cold water being used in mixing, the expansion of the dough on rising causes a great reduction of temperature, as much as 40° below that of fermented bread when placed in the oven; this, with its slow springing until it reaches the temperature of the boiling-point, renders it essential that the top crust should not be formed until the very close of the process. The furnaces, accordingly, are so arranged that the heat is applied through the bottom, and at the last moment, when the bread is nearly baked through, the upper heat is applied, and the top crust formed.

484.




An improved method of making aërated bread is known as the "wine process," and consists in forming a wine from malt by mashing, and afterward setting up the vinous fermentation in closed vessels. Four gallons of the so-called wine are mixed with the necessary water for a sack of flour, drawn into a closed vessel, and aërated—that is, charged with carbonic acid gas, like soda water. This soda water is then mixed with the flour (in strong, closed vessels), and kneaded by arms driven by machinery. The dough formed is drawn off by machinery (thus dispensing with any intervention of the human hand) into the required loaf-sizes, and at the same moment as the carbonic acid gas passes out of it, the dough is raised and vesiculated, and ready for the oven, the whole time required for forming a sack of flour into loaves not being more than half an hour. The effect of the new wine process on the flour is that the gluten cells of the starch are softened and broken up, and the dough is thus entirely altered in its character. Instead of being tough and harsh as formerly, the dough now becomes soft and elastic; it is easily kneaded, requiring only half the power to work the kneading arms, and the atmospheric pressure required in the vessels is only about 20 lbs. to the inch, instead of 90 lbs., as hitherto. The use of such low pressures, besides being a great pecuniary gain, is

485.

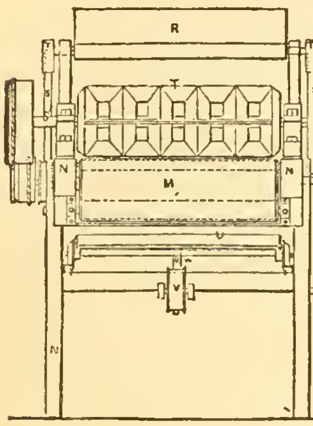


of considerable importance in giving to the bread a soft and beautiful pile-like texture. The dough, when prepared by the wine process, also soaks and bakes with the greatest ease, and at an oven-heat of 100° less than the oven-heat hitherto required for aërated bread. The starch of the flour is now changed into dextrine, while the gluten is uninjured, and the bread has a sweet and agreeable flavor, free from that acidity and bitterness always more or less present in fermented bread.

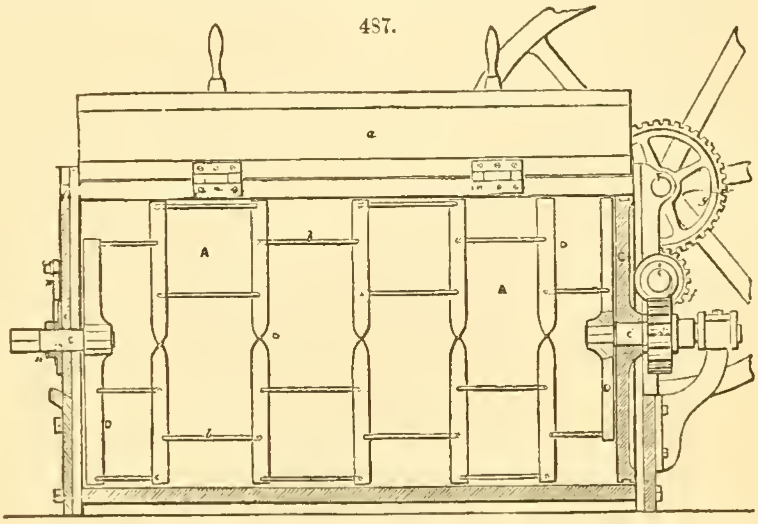
*Bread-making Machinery.*—With Watson's bread-making apparatus, Figs. 485 to 488, the entire operation, from the mixing of the flour and the other ingredients to the final deposit of the dough in the oven, is done by machinery. Fig. 485 is a side elevation. Fig. 486 is an end view. Fig. 487 is

a section of the mixing and expressing vessel, with the agitator; and Fig. 488 is the same, with the expressing-piston in place. *A* is the mixing-cylinder, having a hinged cover *a*, and at one end a sluice-door *L*, which can be raised for the exit of the dough. The agitator, which is first placed in the cylinder, consists of a series of twisted pieces of iron *D*, Fig. 487, which, when rotated by the gearing shown, tend to force the dough out at the sluice-door. The flour, water, etc., being inserted, are thus mixed and left for a time to rise. The agitating apparatus is then removed, and replaced by the piston *C*, Fig. 488, which, by means of the rack and gearing shown, moves so as to force the dough through the opened sluice-door at a regulated thickness and upon an endless web, *M*, Fig. 485. While traveling upon this web the dough is submitted to dusting with flour from the vibrating dust-box *R*. The dough then passes under the dividers *T*, Fig. 486, which separate it into blocks of suitable size. It is then transferred to a truck *U*, which is caused to travel with its load to the oven, where the dough is transferred to another truck which is pushed forward into the oven by hand.

486.

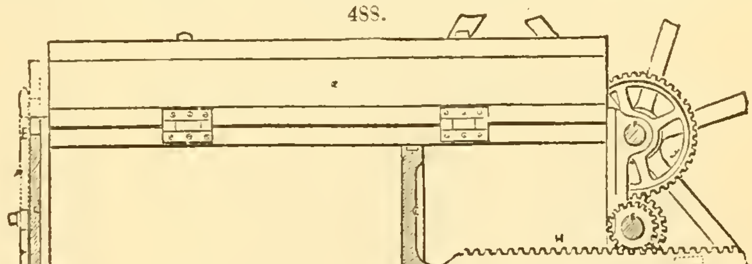


487.



Berdan's automatic oven has two stories. Underneath the oven is a furnace, from which the heat is conducted to and through the oven, by means of fire-brick tubes; and the furnace is so constructed and arranged that, by means of a self-acting damper attached to a piece of metal, which opens and shuts as the metal contracts and expands, the heat in the oven can be regulated and kept constantly at the same temperature. The mercury stands at about 292°. There are four doors or entrances to this oven—two in the lower and two in the upper story. Within the oven is an endless chain, to which arms are attached, and upon which thirty-two forms are laid, about two feet apart. This chain can be moved either by hand or by steam power (the latter being used for convenience and economy in the present case, there being a steam-engine on the premises), and revolves perpendicularly through the oven at just such rate of speed as is required to bake the bread with a single revolution.

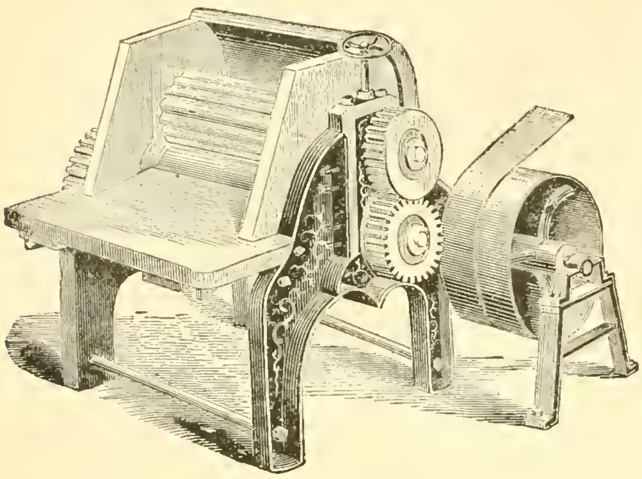
488.



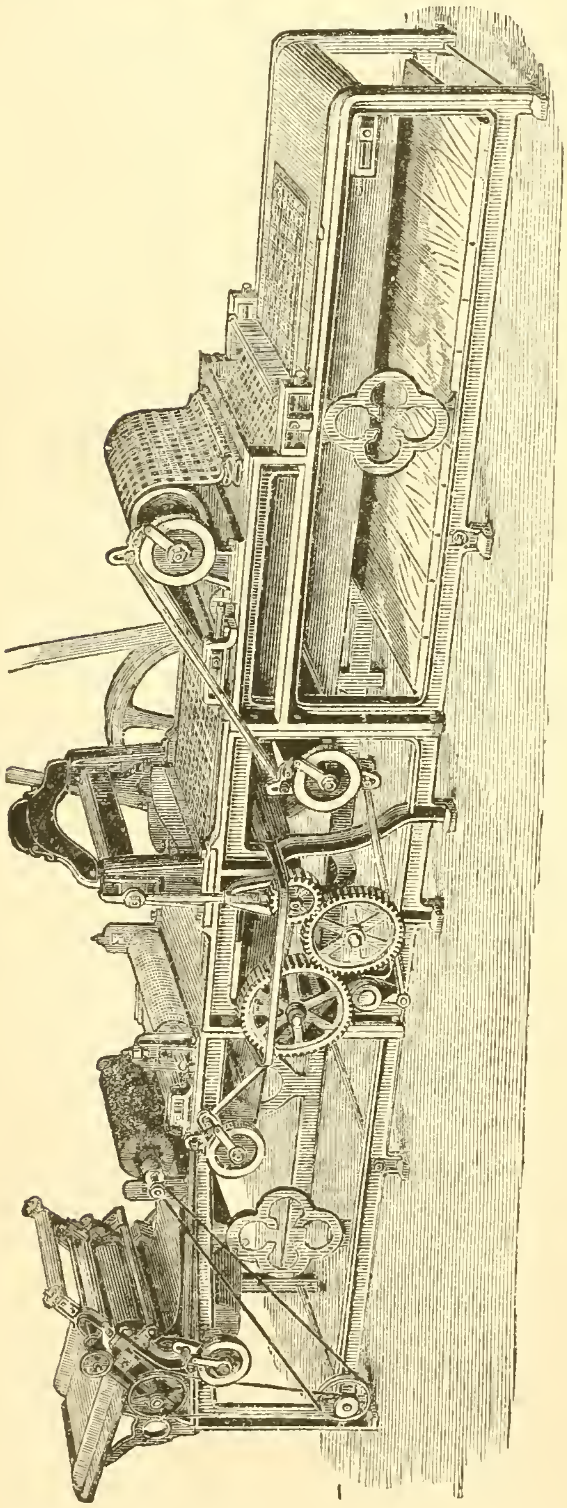
The *pétrisseur*, or mechanical bread-maker, invented by Cavillier & Co., of Paris, consists in a strong wooden trough, nearly square, with its two longest sides inclined, so as to reduce the area of the trough in the direction of its width, and adapt it to the dimensions of a cast-iron roller, the axis of which passes through the ends of the trough; the bottom of the trough is semi-cylindrical, leaving a small space between it and the roller, which space is adjustable by levers. All along the top of the outside of the roller is fixed a knife-edge, which, with the roller, divides the trough into two compartments. Upon the axis of the roller is a toothed wheel, which takes into a pinion; this pinion is turned by a winch, and communicates thereby a slower motion to the roller; and the roller, by its rotation, forces the materials or dough through the narrow space before mentioned left between it and the bottom of the trough—the knife-edge on the top of the roller preventing the dough from passing it. Being thus all forced into one of the compartments, the motion of the roller is reversed by turning the winch the contrary way, which then forces the dough back again through the narrow space under the roller into the first compartment; in this manner the working of the dough, alternately from one compartment to the other, is continued until completed.

Another plan is to make the trough containing the dough revolve with a number of heavy balls within it. The trough in this case is made in the form of a parallelopipedon—the ends being square and each of the sides a parallelogram, whose length and breadth are to each other as five to one. One side of the trough constitutes a lid, which is removed to introduce the flour and water, and the trough is divided into as many cells as there are balls introduced. The patentee states that by

489.



490.



the rotation of the trough the balls and dough are elevated together, and by their falling down the dough will be subjected to beating, similar to the operations of the baker's hands.

Instead of employing a revolving cylinder, it is fixed; an agitator is made to revolve, having a series of rings angularly attached to an axis, extending the whole length of the trough.

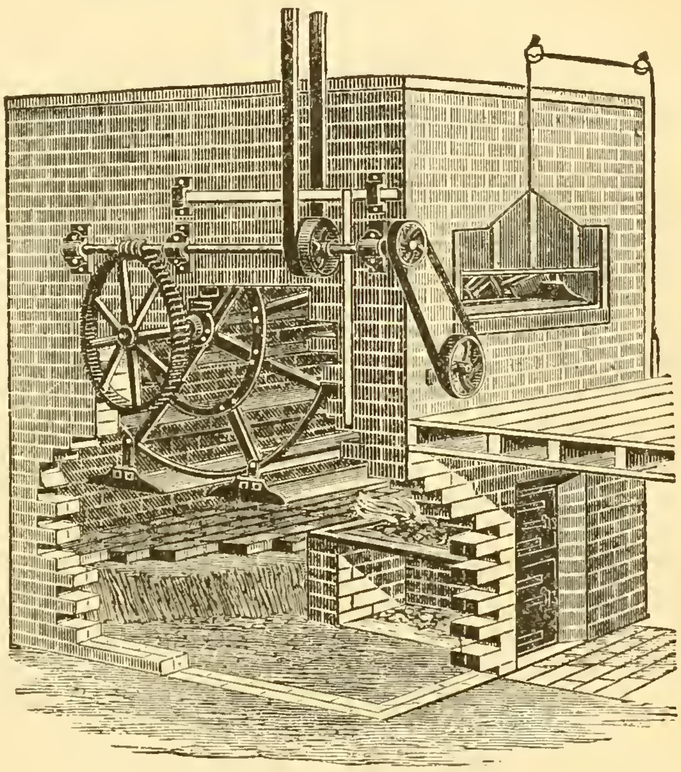
*Biscuit* or *cracker making*, as practised in large baking establishments in this country, includes three distinct operations exclusive of baking: 1, mixing; 2, braking or kneading; 3, cutting or panning. In the first operation, the cylinder-mixer is generally used. It is raised some distance from the floor, and is provided with shoots for flour, milk, butter, sugar, etc. It consists of a nearly cylindrical pan of iron suspended loosely on a shaft which runs through its centre, and is supported by bushes in a cast-iron frame on each side. This shaft carries four stirrers set 6 inches apart, and shaped like an inverted U. They approach within $1\frac{1}{2}$ inch of the circumference of the pan. The driving power is from one end by a toothed wheel gearing into a pinion on another shaft. The outside of the pan is provided with a wheel and toothed segment for lifting the cover and tipping over the can. The capacity is generally 1 barrel of flour, and the time required for mixing is 30 minutes. From the mixer the dough is carried to the brake or roller, of which two kinds are used, viz., the simple and return brake. Table brakes are also employed, but only for very tender dough. In the simple brake, as the dough passes under the iron rollers it is folded, and this process is continued until the dough is perfectly smooth and even in texture. The machine runs at about 180 revolutions per minute. Fig. 489 represents a return-brake with fluted roller, the object of fluting being to accomplish the work more quickly.

From the brake the dough is carried to the cutting-machines, which are of various kinds; those commonly used are the cylinder and the stamper. The latter is in more general employment in this country, as the cylindrical machine is much more expensive without being correspondingly beneficial. The stamper is made in two forms: that which requires the scrap, or the portion between the crackers, to be removed by hand; and the English machine manufactured by Vicars of Liverpool, in which, by an ingenious arrangement of wooden fingers, the crackers are forced downward into a pan, while an ascending apron carries the scrap into a box. A machine of the first class consists of an iron framework, having at one end a pair of rollers which reduce the dough to about an eighth of an inch in thickness. The upper roller is adjustable; the cutter is in the centre of the machine. An endless web of felt passes under the cutter and over a bed-piece of hard wood, covered with rubber three-tenths of an inch thick to resist the force of the cutter. The web is stretched over rollers on each end of the machine, one of which carries a ratchet-wheel moved by an eccentric on the cutter-shaft. The motion is such that when the

stamper is down the web is stationary; and as it rises it moves forward just sufficiently to bring fresh dough into place. The cutters are made of gun-metal and fitted with bristle ejectors for both biscuit and scrap. This machine is used principally for raised crackers. It makes about 160 revolutions a minute, and has a capacity of 30 barrels of flour a day.

Fig. 490 represents an improved form of stamper manufactured by John McCullum of New York. The frame is the same as that of the English machines; the gauging-rollers are heavier, and are provided with a gauge-wheel. The movement of the aprons—of which there are three, viz., that which carries the dough direct to the cutter and the pan, the scrap elevator, as also that of the brush and gauge rollers—is by means of eccentrics on main and cutter shafts working ratchets. This motion is easily adjustable to alter the movement of the aprons and rollers. An improvement on this machine is used in the extensive establishment of Messrs. E. J. Larrabee & Co. of Albany (to whose courtesy we are indebted for the facts presented in this article), which affords a continuous feed, and in which the biscuits and scraps are separated by a finger device, the biscuits going into pans and the scrap to the brake to be worked over. The machine makes 60 revolutions on soft dough and 80 on hard. Its capacity is 20 barrels of flour a day. The cutters make from 18 to 40 biscuits at each motion.

491.



In the so-called "snap" machine the box which contains the dough has its bottom perforated with round holes beveled inwardly. The dough being placed in the box, screws driven by suitable gearing force down a piston, which causes a certain amount of the dough to be driven out of the holes in the box. Knives placed opposite each hole then cross over and sever the exuded portions, which fall upon pans placed to receive them. This machine has a capacity of 20 barrels of flour in 10 hours. The "Rout press" is similar in construction, the dough being pressed through dies and carried to pans, when it is cut into suitable lengths.

In the mechanical manufacture of bread and crackers, the process of baking has been greatly improved in this country. Two forms of oven are chiefly used, viz., the revolving wheel and the endless chain. Fig. 491 shows a section of the Raney oven. It is built of brick, the walls being 8 inches thick. Passing through the chamber is a shaft, on which is fixed a wheel, to which are hung the pans. The diameter of the wheel is such that during the revolution each pan is brought within 18 inches of the fire. The fire is built upon an open grate flush with the floor of the furnace, the ash-pit being immediately under it. The flue is situated on a level with the grate and at the back of the oven. The top or crown is built in the form of a double arch, which forms concavities to receive the superheated air and steam. In this way the darkening of the tops of the crackers by excessive heat is prevented. The wheel carries twelve shelves, which, being hung loosely, always remain level. Motion is imparted to it by means of a worm working on a cog-wheel attached to the shaft. The speed is regulated by a brake-wheel on the face of the oven. The door of each oven, 18 inches high and extending across the oven, is provided with an adjustable closer. The shelves carry 4 pans, which are made of either sheet-iron or coarse wire-netting, according to the kind of dough to be baked. In the operation of baking, the pans being inserted, the baker starts the wheel, which revolves toward him from above downward; this brings the shelf half-way to the fire, and the operation is repeated until the first shelf and baked crackers appear at the opening. The temperature ranges from 250° to 450°. The time required varies according to the size of the biscuits or other material. Bread usually requires 35 minutes; raised crackers 3 minutes; fancy crackers from 3 to 6 minutes. The capacity of the oven is 50 barrels of flour a day. In the endless-chain oven the shelves are attached by pulley-blocks to an endless chain which passes over the fire.

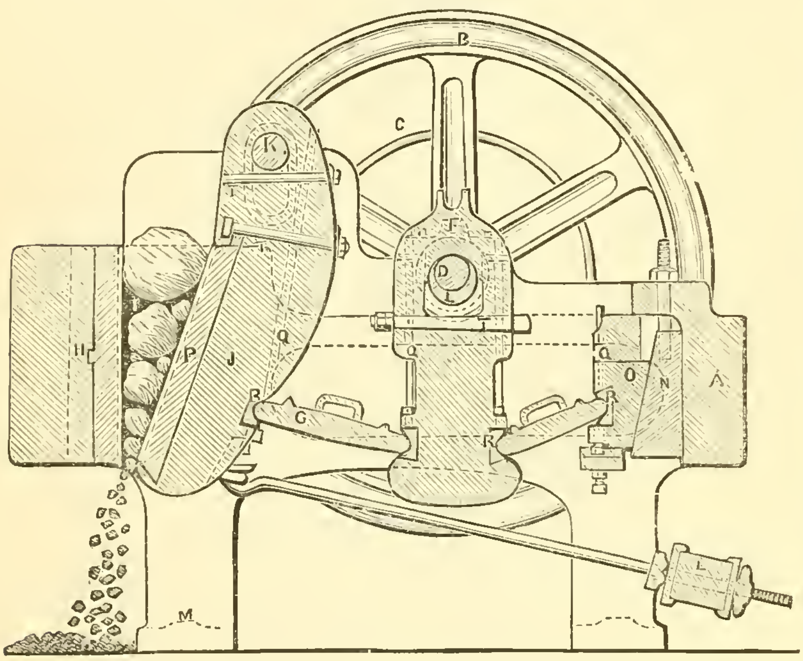
For principles of bread-making, see "Report on Vienna Bread," by Professor Hosford, in "Reports of U. S. Commissioners to Vienna Exposition, 1873." G. H. B.

BREAKER, or CRUSHER. A machine for breaking and crushing minerals which reach the surface in large solid blocks or masses into fragments that can be easily handled, preparatory to placing them in machines for reducing them to still smaller fragments or to powder. The sledge is the simplest and most common tool for this purpose; and it is followed by spalling hammers, until none of the fragments are much larger than the fist. Until within a few years this was the common and only way of breaking up ore into sizes suitable to be fed into mortars of stamp-batteries; and it is still used where only small quantities are to be broken, and the extent of the operations does not justify the expense of obtaining suitable machines for the purpose.

The first attempts upon the Pacific coast to substitute machine for hand labor in spalling ore were in the direction of stamps of unusual weight, raised by cams to a height of 4 feet, and allowed to

drop upon the mass of rock to be broken. Stamps of this kind, either single or two in a battery, were placed at the superb mills erected near Aurora, at the Real del Monte, and at the Antelope. They weighed 2,000 lbs. each. There were no mortars, but a solid bed or anvil was surrounded with massive grates, made of bar iron, through which the fragments could drop. Masses of ore, from 1 to 2 feet in diameter, could be rolled in and subjected to a succession of blows. The two heads could break up about 2 tons an hour, but with an enormous expenditure of power, as is evident when we consider that for each blow a ton weight of stamp was to be raised 4 feet, and also that the smaller the mass to be broken the greater was the force of the blow. Thus, when a mass of quartz, say 6 inches in height, lay upon the anvil, the stamp fell upon it from a height of 3 feet 6 inches; but when a block 2 feet high, which needed a much harder blow, was upon the anvil, the stamp fell only 2 feet. Similar stamps were in use at Washoe and at Virginia, but were soon abandoned because of their manifest defects and cost.

492.




At the Quincy mine, on Lake Superior, heavy hammers have been used for breaking up coarse gangue containing ore, which are managed after the manner of the machines in use for breaking up large ore-masses. They are especially serviceable for coarse pieces of native copper, which cannot be broken in the crushers, in separating the copper from the gangue united with it, and in hammering clean the lumps of copper.

*The Blake Breaker and Crusher*, invented by Mr. Eli Whitney Blake of New Haven, Conn., is one of the most effective machines of its class. Fig. 492 shows a side-view or elevation of this machine. The circle *D* is a section of the fly-wheel shaft, which should make from 225 to 250 revolutions per minute. The larger circle *L*, inclosing *D*, is a section of the eccentric. *F* is a pitman or connecting-rod, which connects the eccentric with the toggles *G G*, which have their bearings forming an elbow or toggle joint. *H* is the fixed jaw; this is bedded in zinc, a quarter of an inch thick, against the end of the frame. *P P* are chilled plates against which the stone is crushed; when worn at the lower end they can be inverted, and thus present a new wearing surface. The cheeks *I I* fit in recesses on each side, and hold the plates in place; by changing the position of the cheeks from right to left, when worn, both will have a new surface. *J* is the movable jaw; this is supported round the bar of iron *K*, which passes freely through it, and forms the pivot upon which it vibrates. *L* is a spring of India-rubber, which is compressed by the forward movement of the jaw, and aids its return. *M M* are bolt-holes. *B* is the fly-wheel; *C*, the driving-pulley; *Q Q Q Q*, oiling-tubes; *R R R R*, steel bearings; *T*, bush and key. Every revolution of the crank causes the lower end of the movable jaw to advance toward the fixed jaw about one-fourth of an inch and return. Hence, if a stone be dropped in between the convergent faces of the jaws, it will be broken by the next succeeding bite; the resulting fragments will then fall lower down and be broken again, and so on until they are made small enough to pass out at the bottom.

The following table shows the principal facts that relate to the sizes of machines that are used generally for the making of road-metal:

*Table of Sizes and Capacity, Blake's Stone Breaker.*

| NUMBER. | Size, or receiving Capacity. | Product per Hour in Cubic Yards.* | Total Weight. | Proper Speed. | Horse-power required. |
|---|---|---|---|---|---|
| | Inches. | | | | |
| A | 10 × 4 | 3 | 4,000 | 250 | 4 |
| 1 | 10 × 5 | 3 | 6,700 | 180 | 5 |
| 2 | 10 × 7 | 5 | 8,000 | 250 | 6 |
| 3 | 15 × 5 | 6 | 9,100 | 180 | 9 |
| 4 | 15 × 7 | 6 | 10,490 | 180 | 9 |
| 5 | 15 × 9 | 7 | 13,360 | 250 | 9 |
| 6 | 15 × 11 | 7 | 11,600 | 180 | 9 |
| 8 | 20 × 15 | .. | 32,600 | 150 | 12 |
| 7 | 15 × 13 † | .. | 11,760 | 180 | 9 |
| 9 | 24 × 18 † | .. | 37,500 | 125 | 12 |
| 10 | 16 × 12‡ | 6 | 7,000 | 230 | 9 |

* The amount of product depends on the distance the jaws are set apart, and the speed. The product given in the table is due when the jaws are set 1½ inch open at the bottom, and the machine is run at its proper speed and diligently fed; but it will also vary somewhat with the character of the stone. Hard stone or ore that breaks with a snap will go through faster than sandstone. A cubic yard of stone is about one and one-third tons.

† Coarse or preliminary breakers. ‡ Plaster crusher.

To make good road-metal from hard compact stone, the jaws should be set from $1\frac{1}{4}$ to $1\frac{1}{2}$ inch apart at the bottom. For softer and for granular stones they may be set wider.

*Hall's Breaker* is similar in principle and mode of action to the Blake machine, but differs in various modifications and details. The movable jaw is made in two pieces, each half the width of the fixed jaw; and the parts are driven by separate toggle-levers and eccentrics, so that they make alternate strokes. This alternate movement is turned to account to draw back the jaws, the forward movement of one jaw drawing back the other, and *vice versa.* The faces of the movable jaw are detachable, and are held in place by wedge-shaped bolts which may be easily tightened. The fixed jaw also has two sets of faces, the upper set being of wider pitch than the lower, and being so arranged with respect to the movable jaw that the teeth of the latter work opposite a space in the fixed jaw. In the lower parts of the fixed jaw, on the other hand, the pitch is finer, and the teeth are directly opposed to the teeth of the movable jaw. The arrangement is claimed to give the jaws an improved cubing action.

*Brown's Breaker* consists of an upright circular shell, in which is a vertical shaft, the upper extremity of which is pivoted in a ball-and-socket bearing in the cover surmounting the shell or case. The lower end of the shaft is pivoted in the hub of a bevel-gear. This gearing is placed in an eccentric position with reference to the centre of the hub. The breaking head, which is placed near the upper portion of the shaft, receives an eccentric gyratory motion from the eccentrically placed bearing in the hub of the gear below, and advances successively toward every portion of the outer wall, crushing the ore between chilled faces on both the wall and the head. It is claimed that a breaker of this type weighing 7,500 lbs. will crush 10 tons of ore per hour, and that one of 20,000 lbs. has a capacity of 20 tons per hour.

*The Alden Breaker* is designed to work upon material on the principle of abrasion, instead of on the generally adopted principle of direct compression or impact. It breaks, crushes, and pulverizes by rasping and rubbing fragment upon fragment between the dies, and upon the horizontally corrugated steel faces thereof; the motion of the rubbing surfaces being obtained by the oscillation of the dies. They both swing at the same time, in one and the same direction, and to an equal extent. At their delivering extremities they are held together (closely or otherwise, according to the character of production wanted) in such a manner that the distance apart from face to face is the same at all points of the stroke. The dies are hung upon shafts, the ends of which project through the sides of the frame, and take connecting-rods which at their other extremities receive the studs that jut out from the sides of a rectangular yoke. This yoke surrounds the free hanging ends of the dies and moves on a nearly horizontal plane, alternately pushing and pulling the dies within it the full distance of the stroke, and imparting the rubbing effect. The regulation of the set of the dies to different grades of production is effected by means of adjustable steel keys. The connection between the yoke and crank is direct by way of a pitman. The crank-shaft, fly-wheels, and pulley do not require special mention.

*Table showing Capacities, etc., of Alden Breaker.*

| NUMBER. | Dimensions of Receiver. | Gross Weight. | Capacity to crush and pulverize to 40 mesh fine. | H. P. requisite. |
|---|---|---|---|---|
| | | Lbs. | Lbs. per Hour. | |
| 4 | $14 \times 3$ | 18,000 | 1,500 | 15 to 20 |
| 6 | $12 \times 3$ | 10,000 | 1,000 | 12 to 15 |
| 7 | $10 \times 3$ | 4,500 | .... | 10 |
| 8 | $10 \times 1\frac{1}{2}$ | 800 | 400 | 5 |
| 9 | $5 \times 1\frac{1}{2}$ | 600 | 150 | 2 |
| 10 | $1\frac{3}{4} \times \frac{5}{8}$ | 30 | .... | hand-power. |

Crushing Rolls.—1. *Ore-Rolls.*—By means of crushing rolls, gangue of about the size of the fist can be reduced sufficiently to separate the dead rock from the ore mixed with it. Fig. 493 will serve to give an idea of the general form of the crusher which has for many years been used in Cornwall for ore-dressing. The rolls are supported by very strong bearings, in a frame strengthened by wrought-iron bolts. In the construction here shown, the rollers are kept in contact by India-rubber springs or buffers of great elastic force, one on each side of the frame. Each buffer is composed of

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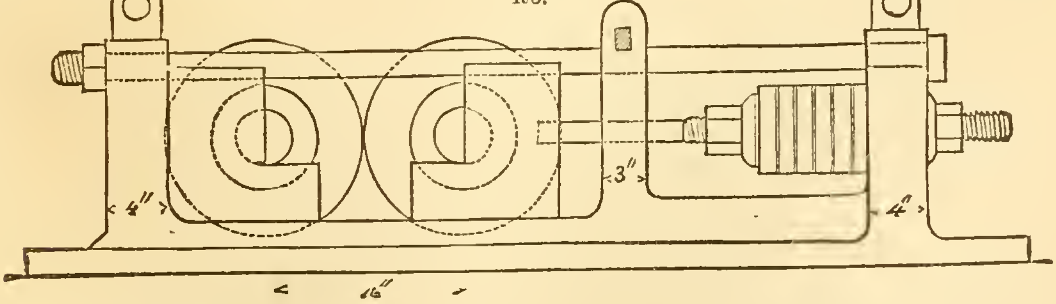



6 rubber disks an inch thick, separated by a disk of iron a quarter of an inch thick. The necessary initial pressure is obtained by means of two strongly-made screws in the axes of the buffers; and by screwing up or unscrewing the nuts on these screws the pressure may be increased or diminished, according to the necessities of the case. It is evident that it would not answer to rigidly fasten the rolls in contact. The accidental dropping of a steel tool, such as a drill or a hammer-head, between

them, would break the machine; and moreover, they would not crush as fast and well without a certain amount of yielding to the materials carried through between them. The use of rubber springs offers a method of giving the necessary resistance, which increases with the degree of separation of the rolls, whereas with weighted levers the pressure is constant. In practice it is found that the product of rolls geared together is greater than when one is carried around merely by the friction of the stuff crushed. It is also usual to have three or more rolls where the crushing is wholly done by rolling. The upper pair are set so as to take in large masses; and to increase the hold of the surface of the rollers upon the masses, they are made fluted. The fragments falling from this first pair of rolls are divided between two pairs set below and pressed closely together. The diameter of crushing rolls varies from 14 to 34 inches (27 inches is a common diameter), and the length or breadth of face from 12 to 22 inches. The rolls at the mine of Devon Great Consols in Cornwall are very large, having 34 inches diameter and 22 inches face, and a pressing force on the rolls of 458 cwt., revolving 7 times per minute, and crushing 65 tons in 10 hours, at a cost of 2¼ pence per ton.

At present smooth rolls are in common use for dressing ores. The middle products from the jigging process—in which, for instance, galena is intermixed with blende or gangue, and which, as a rule, are not more than .78 inch in diameter—are ground in rolling mills with less diameter of rolls. In the coarse rolls, which work with the very heavy pressure of from 20 to 25 tons counterweights, it is advisable not to exceed a velocity of the circumference of over 65 to 72 feet, because otherwise fractures easily occur, on account of the resistance of the counterweight. In the Rhenish ore-dressing establishments, where rubber or steel springs are used for pressing the rolls together, 196 and even 294 feet velocity of circumference is allowed, without, however, increasing the working capacity, with the consequently reduced pressure of rolls, as compared with slower work and a heavier pressure. The more or less soft nature of the ore must in each case decide which treatment it is advisable to use. The use of springs has lately been preferred, in order that the softer ores may not be crushed too fine and loss be thereby created. The danger of fracture is essentially lessened by transmitting the driving power by means of belts or friction-rolls. In such contrivances for fine crushing the position of the rolls is fixed by set-screws. The two axles on which the annular rolls are fastened are provided with a pair of toothed wheels working into each other, and such a length must be given to the teeth that they will not be thrown out of gear when the rolls separate. Coarse rolling-mills have, therefore, involute gearing with very deeply cut teeth. The annular roll is worn away rapidly by hard material, and is therefore generally made of either chilled iron or cast steel. It is essential to be able to turn down the rolls from time to time, because they wear unevenly.

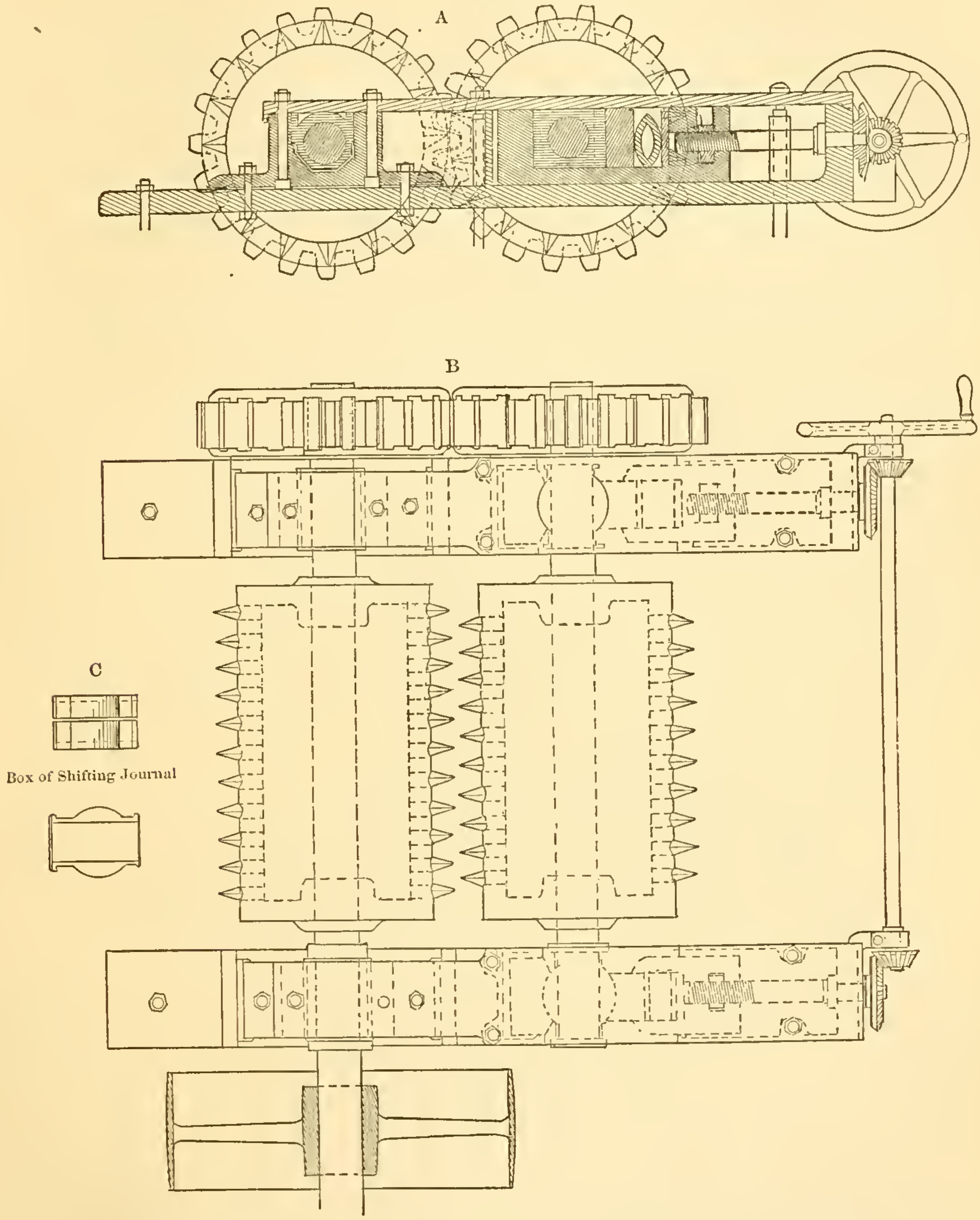
From 50 to 60 tons of rolling stuff, varying as the gangue mixed with the ore is silicious or calcareous, can be worked up in 10 hours in a coarse rolling-mill constructed on the English model, and requiring 10 horse-power to run it. From 5 to 20 tons can be worked up in the same time in a flat rolling-mill, with from 2 to 4 horse-power. In Schwarzmann's friction rolling-mill for fine reduction at Ammeberg, Sweden, a rotating flat disk, driven by the engine, is inserted between each pair of rolls, and carries them with it, working in a similar manner to a collar-mill.

Among the various other forms of ore-crushers, akin to rolls, are the following: 1. Two conical disks are keyed to inclined shafts having powerful set-screws to adjust the width of the space between the disks. The ore or stone is fed into a shoot, and, falling between the inclined disks, is subjected to a pressure as it passes into the gradually contracting space, and is thus crushed. 2. A concentric roller, with teeth of varying sizes as the throat narrows, bites upon the ore, which is gradually comminuted between the jaws as the ore is rocked. Mills for finely pulverizing ores will be found treated under Mills, Ore.

2. *Coal-Crushers.*—The comminution of coal takes place either for the purpose of breaking up the coal obtained into pieces of a suitable size for the market, or to separate the coal from the accompanying foreign ash-producing portions—slate, iron pyrites, and earthy coal—and then to wash it clean. In both cases the endeavor is so to arrange the rolls that they act on the pieces of coal as little as possible in a crushing or grinding way, but more in a splitting manner, in order to obtain the smallest possible amount of worthless coal-dust in the first case, and in the second to avoid grinding into fine dust the soft pieces of fuller's clay and clay-slate, which cannot be separated from the fine coal-dust in the further dressing. Rolls for breaking up anthracite were first employed in Pennsylvania in the year 1843, according to Gätzschmann. Afterward diamond-shaped, blunt, tooth-like projections working toward one another were added to the rolls in that locality, while the body of the rolls themselves, made of cast-iron, was provided with indentations arranged in right and left spirals crossing each other. The toothed rolls, on the one hand, produced much useless coal-dust, and, on the other, it was found necessary to throw away a roll when a few teeth were broken out. Cylindrical rolls have been advantageously used with cast-steel teeth inserted, whose peculiar construction is shown in Fig. 494, *A*, *B*, *C*. Smooth cylindrical holes of exactly equal diameter are bored radially, in lozenge-shaped places opposite each other, in the casing of the rolls, and into these holes the steel projections, provided with cylindrical shanks so as to fit accurately, are driven firmly. The lancet-like projections are slightly bent in the direction of the motion, in order to seize and split the pieces of coal with more certainty. If a tooth breaks off, the shank still remaining in the cylinder is driven through the hole and a new tooth is inserted. For this reason the toothed roll, though at first cost somewhat dearer than the old cast-iron one, is much cheaper in the end. Besides, the work is increased with the same power, and the loss in worthless dust is diminished. The machine represented likewise shows various important improvements for the safety of its working in regard to the motion and bearings of the shifting roll, which can be recommended for ore-crushing mills also. The bronze bearings, for instance, are provided above and below with parallel planed surfaces, so that they can be shoved into a box-like cavity in the roll frame. The middle portion of the bearings forms an upright cylinder, from which the ends of the bearings project sidewise like annular shoulders. Elliptical cast-iron rings lie, as brake-pieces, between the bearings and the set-screws; the latter are ad-

justed equally by means of a motion common to both. If such a brake-ring gives way, the roll, with its bearings set free, can recoil without obstruction, while the other bearing turns on its cylindrical part. By means of this arrangement, which works in a similar manner to the ball-joint journals, as

494.




smooth a revolution as possible of the axle is produced with diminished friction and wear, notwithstanding the heavy vibrations to which the movable roll is exposed. The box-like frame-pieces are each provided with an accurately-fitting cover, which prevents the lifting and sliding of the movable bearing.

In Germany, rolls which are provided with sharp, projecting ribs are used in the crushing mills of coal-washing establishments. To prevent the interfering of these ribs, they are wound round the cylindrical roll in steep helices laid crosswise, so that lozenge-shaped depressions remain between the ribs; but even for such coal-washing establishments the improved American toothed rolls with narrower roll-space may be adapted. See "The Mechanical Dressing of Ores and Coal," by E. F. Althan, in "Reports of Judges of Group I., Centennial Exposition."

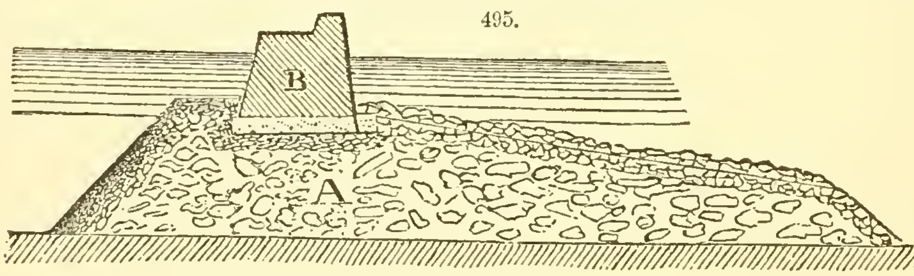
BREAKWATER. A kind of artificial embankment, dike, or rampart, formed of large stones, and erected for the purpose of protecting the entrances of harbors or roadsteads from the effects of violent winds, by breaking the force of the waves of the sea; the shipping, moored behind it, lying perfectly secure. The most celebrated works of this description are those of Cherbourg in France, Plymouth, Portland, and Holyhead in England, and Delaware Bay in this country. The experience obtained by the construction of breakwaters, and by the action of waves upon coasts exposed to their greatest violence, establishes the principle that blocks of stone of large dimensions only can be depended upon to retain their places. Mr. James Walker, President of the British Institution of

Civil Engineers, advanced the opinion in 1841 that a partial vacuum is created by the action of the waves, and the atmospheric pressure being taken off for an instant, the mass of stone is the more readily influenced by the forces acting upon it. (*Civil Engineer and Architect's Journal*, September, 1841.) If the whole atmospheric pressure were taken off the surface, it would be equivalent to the removal of a weight represented by a column of rock $11\frac{1}{2}$ feet deep, weighing 1.75 lb. to the cubic foot. Under such circumstances, and exposed to the action of a wave 20 feet high, which is capable of moving masses of rock $7\frac{1}{2}$ feet deep, stability would be insured only by the addition of this amount to the $11\frac{1}{2}$ feet. But as it is not probable that a large proportion of the atmospheric pressure is ever thus removed, and as 22 feet is regarded as the maximum height of waves, a depth of solid stone of 15 feet, used as a coping, would probably resist all action of the waves.

*Best Form of Breakwater.*—From the fact that any settlement of the foundation is far more perilous to a vertical than to a sloping wall, there seems good ground for believing that the ordinary method of forming the low-water parts of deep harbors with large masses of rubble-stone or of concrete blocks, is in most circumstances the best and cheapest kind of construction when a vertical wall is to be adopted. Loose rubble or blocks of concrete, after being acted upon by the waves, are less liable to sink or to be underwashed, than when a vertical wall is founded upon a soft bottom. Loose concrete blocks above low water form an excellent protection to the upright wall. Two precautions should, however, be kept in view: first, the wall should be founded at a sufficiently low level to prevent underwashing 12 to 18 feet below low water; and second, in all cases where the structure is to act simply as a breakwater and not as a pier, there should be no parapet, the absence of which relieves the foundation. When pitched slopes are adopted, great benefit will be found to accrue from leaving a wide foreshore at the bottom or toe of the slope. Much, however, depends on local peculiarities in selecting the best design for any work, and the nature of the bottom is in all cases important. Where the bottom is soft, a high vertical wall should not be attempted.

*The Cherbourg Breakwater* was begun in 1783. The building of the wall was commenced upon upright cones of timber, and each cone was intended to be about 150 feet in diameter at the base, 60 feet at the top, and about 60 or 70 feet high, the depth of water at spring-tides, in the line in which they were sunk, varying from 56 to 70 feet. They were also intended to be filled with stones to the top, and, after allowing some time for settling, the masonry was intended to be commenced upon them. But a few of these cones only were constructed, when, in consequence of the difficulty of the undertaking, the whole was covered with large stones thrown in at random. As this breakwater is intended also as a military construction, for the protection of the roadstead against an enemy's fleet, the cross-section shown in Fig. 495 was adopted for it. Profiting by the experience of many years'

495.

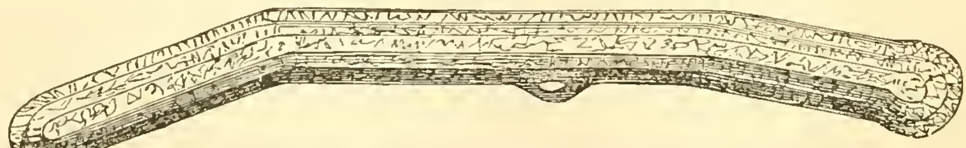



observation, it was decided to construct the work that forms the cannon-battery of solid masonry, laid on a thick and broad bed of béton. The top surface of the breakwater is covered with heavy, loose blocks of stone, and the foot of the wall, on the face, is protected by large blocks of artificial stone formed of béton. The experience acquired at this work has conclusively shown that breakwaters formed of the heaviest blocks of stone are always liable to damage in heavy gales when the sea breaks over them, and that the only means of securing them is by covering the exposed surface with a facing of heavy blocks of hammered stone carefully set in hydraulic cement.

The wall $B$ is of rubble masonry faced with granite, and rises to a height of 6 feet above highest water. This is protected by a foreshore of great blocks of stone, $A$, on the outer side, which extend in a slope of 120 feet to the depth of 21 feet below low-water mark. This nearly vertical wall (the slope of its sides being $\frac{1}{6}$ to 1) is 36 feet 3 inches wide at base and 29 feet 3 inches wide at top. The altitude of the breakwater is 72.3 feet, and the base of its sea-slope measures 228.5 feet. Its length is nearly 2 miles. It is composed of two unequal arms, joined at an angle of 170°, with the opening toward the land. The work was completed in 1854, and its total cost is stated to have been $15,460,000.

*The Plymouth Breakwater*, Figs. 496 and 497, was commenced in 1812. It is composed of blocks of stone from $1\frac{1}{2}$ to 2 and 3 tons in weight, and consists of a central part 1,000 yards long, and two

496.



Plan of Plymouth Breakwater.

wings each 350 yards long, directed toward the sea, and forming angles of 158° with the centre portion. A transverse section taken through the breakwater shows an average base of 290 feet, and

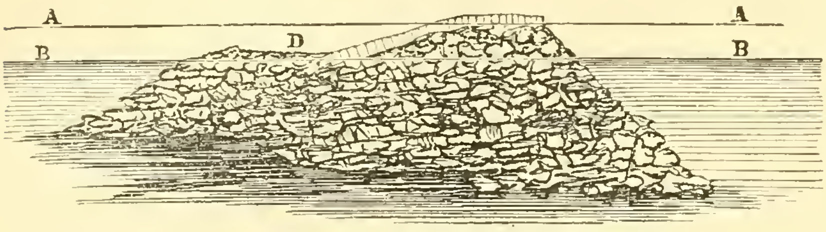
*Table showing Proportions of Large Breakwaters.**

| NAME. | Kind of Work. | General Slope of Outer Face. From Bottom to near Low Water. | Near Low Water. | Up to High Water. | Above High Water. | Inner Slopes. Above High Water. | Below High Water. | Top above High Water. | Level of Top of Loose Rubble below Low Water. | Level of Foundations of Wall below Low Water. |
|---|---|---|---|---|---|---|---|---|---|---|
| **Sloping Breakwaters.** | | | | | | | | Feet. | | |
| Plymouth | Pitched slopes above high water, loose rubble below | $1\frac{5}{8}$ to 1 | 4 to 1 | 5 to 1 | 5 to 1 | 2 to 1 | 2 to 1 | 3 | 0 | 0 |
| Portrush | Slopes of loose rubble | $1\frac{3}{4}$ to 1 | 6 to 1 | 3 to 1 | $1\frac{1}{8}$ to 1 | $1\frac{1}{2}$ to 1 | 1 to 1 | 16 | 0 | .. |
| Kingstown | Pitched slopes of rubble | $1\frac{3}{4}$ to 1 | 5 to 1 | 5 to 1 | 5 to 1 | $\frac{1}{8}$ to 1 | $\frac{1}{8}$ to 1 | 15 | 0 | 0 |
| Holyhead | Slopes of loose rubble | 1 to 1 | $5\frac{1}{2}$ to 6 to 1 | $5\frac{1}{2}$ to 6 to 1 | ...... | ...... | ...... | ...... | .. | 0 |
| **Composite Breakwaters.** | | | | | | | | | | |
| Portland | Slopes of loose rubble, with plumb wall above high water | $1\frac{1}{2}$ to 1 | 5 to 1 | 5 to 1 | 5 to 1 and plumb wall. | Plumb wall | 1 to 1 | 25 | 0 | .. |
| Cherbourg | Slopes of loose rubble, with plumb wall above | 2 to 1 | 7 to 1 | 7 to 1 | ...... | $7\frac{1}{2}$ to 1 and $\frac{1}{6}$ to 1 | 1 to 1 | $12\frac{1}{2}$ | 0 | 0 |
| Alderney | Slopes of loose rubble, with plumb wall above | 2 to 1 | 5 to 1 | Wall $\frac{1}{2}$ to 1 | $\frac{1}{2}$ to 1 and plumb | Wall $\frac{1}{3}$ to 1 | $1\frac{1}{4}$ to 1 | 25 | 0 | 12 |
| Cette | Slopes of loose rubble, with plumb wall above | $1\frac{1}{2}$ to 1 and 6 to 1 | $3\frac{1}{2}$ to 1 | Plumb wall. | Plumb wall | ...... | 1 to 1 | $12\frac{1}{2}$ | .. | .. |
| Pulteneytown | Slopes of loose rubble, with plumb wall above | From bottom to 15 feet below low water, 1 to 1 and 7 to 1. | ...... | Plumb wall. | Plumb wall | ...... | ...... | 6 and 21 | 15 | 18 |
| **Vertical Breakwaters.** | | | | | | | | | | |
| Dover | Solid Masonry | $\frac{1}{4}$ to 1 | $\frac{1}{4}$ to 1 | $1\frac{1}{4}$ to 1 | $\frac{1}{4}$ to 1 and cavetto | $\frac{1}{4}$ to 1 | $\frac{1}{4}$ to 1 | 23 | .. | 45 |
| Aberdeen | Concrete | $\frac{1}{8}$ to 1 | $\frac{1}{8}$ to 1 | $\frac{1}{8}$ to 1 | $\frac{1}{8}$ to 1 | $\frac{1}{8}$ to 1 | $\frac{1}{8}$ to 1 | 11 | .. | 20 |

* From "The Design and Construction of Large Harbors," Stevenson.

the breadth at the top is 48 feet, with an average depth of water at low spring-tides of 36 feet. The side next the sea is sloped in the proportion of 1 perpendicular to 5 horizontal, and the side next the land is 1 to 2; these sides were not originally intended to have so great a slope, but, in consequence of the violence of the waves during its construction, it was thought proper to increase them, as executed. The stone was raised in large blocks, some of which contained 10 tons, and were thrown into the sea in the direction set out for the breakwater, care being taken that the greater number were deposited upon the outer slope. After a number of these large masses had been lowered, a smaller class of stones, quarry rubbish, rubble, and lime screenings, were thrown in to fill up the interstices, and close all the cavities; these found their position, by the action of the sea, and the great mass became, as it advanced, perfectly wedged together. The object of this breakwater is to protect the harbor, which is only open to the south. It is situated upon the inner of three reefs of rock which lie outside the port, and closes what was once a central passage, leaving open passages to the east and west. Its cost was $8,500,000, or $1,666 per running foot.

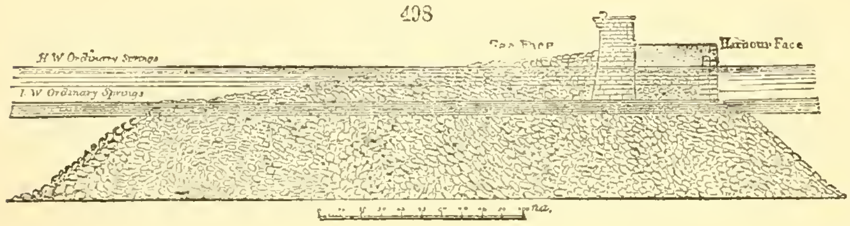
497.




Section of Plymouth Breakwater.—*A A*, high-water spring tides; *B B*, low-water spring tides; *D*, the foreshore.

*The Holyhead Breakwater*, Fig. 498, was designed by Mr. J. M. Rendel. The coast about Holyhead, Wales, is low, with the exception of Mount Carmel and the North and South Stacks. The bay, lying to the north of the island, is 7 miles wide at its entrance and about 5 miles in depth, lying open to the north and the west. The accepted plan of Mr. Rendel consisted of a north breakwater 5,360 feet long from the coast line, and an east breakwater about 2,000 feet long (these two breakwaters inclosing between them an area of 267 acres of available water-space), and of a packet-pier 1,500 feet long situated within the inclosed area. The east breakwater was subsequently abandoned, and the northern one alone retained. This was lengthened first by 2,000 and then by 500 feet, making its total length 7,860 feet from the shore, and enabling it to shelter a roadstead of 400 acres of deep water, in addition to the 267 acres of water-space already mentioned.

498




The north breakwater consists of a substructure or rubble mound of stone or *pierre perdue*, upon which is erected a substantial stone superstructure. The stone is a quartz rock, and was deposited in the sea from wagons running on a temporary wooden staging, constructed with five lines of railway in communication with lines to the quarries in Holyhead mountain. The rubble mound is of great size, the average depth of water at low-water spring tides being 40 feet, and the greatest depth 55 feet; the rise of the tide is 18 feet. The inclination that is given to the foreshore, or the slope from low water to the superstructure, is nowhere steeper than 7 to 1; and this inclination continues up to about 10 feet below low-water mark, where the mound assumes a slope of 2 to 1 to about 25 feet below low-water mark, and somewhat flatter than 1 to 1 from that point to the bottom. On the harbor side the slope of the mound is about 1 to 1. At the level of low water the mound is nowhere less in width than 250 feet, and in 50 feet of water it is 400 feet wide at the base. It contains about 7,000,000 tons of stone.

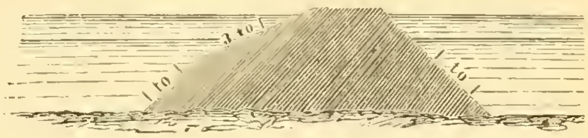
The rubble mound having been formed and consolidated by the continual action of the sea, the superstructure was erected. This consists of a large solid central wall of massive masonry. Many of the stones are of large size, some weighing upward of 15 tons, and the work is set in lias-lime mortar. The foundations for this wall are laid at the level of low water, for which purpose the loose stone of the mound had to be excavated. The wall was built as near as circumstances would admit to the inner edge of the stone deposit, in order to allow as long a foreshore on the sea side as could be obtained. This solid wall is carried up to a height of 38 feet 9 inches above low water, and upon it is a promenade, surmounted on the sea side by a massive parapet. At 27 feet above low water, on the harbor side of the central wall, there is a lower quay 40 feet wide, formed by an inner wall, built at a distance from the central wall, the intermediate space being filled in. The main object of the superstructure is to shelter the interior harbor more effectually, and to prevent the loose stone deposit from washing into the port. The head at the end of the breakwater is 150 feet long by 50 feet wide. It is founded on the rubble mound at a level varying from 20 to 28 feet below low water, and is built of ashlar masonry. The extreme height from the bottom of the sea to the top of the breakwater is 93 feet. The total cost of the work was $6,219,400, whence it follows that the cost per foot run was about $791. It was completed in 1873. See *Engineering*, xiv., 253.

*The Portland Breakwater* commences with a pier, which starts from the island of Portland, on the southern coast of England, near the point where it is connected with the mainland, and, after proceeding for a short distance in the same direction as the pier, turns and extends in a northeast direction for a distance of 6,000 feet. The breakwater proper is a rubble bank, with a width at the base of 300 feet, at low-water level of from 90 to 100 feet, and at the top of 60 feet. The slopes on the

sea face, from the bottom to a height of 12 feet, are 6 to 1; on the harbor face, $1\frac{1}{4}$ to 1. The sheltered area is about 2,100 acres up to low-water line. This work was begun in 1849 and completed in 1872. Its cost was $5,065,000, or about $844 per running foot. See *Engineering*, xiv., 118.

*The Delaware Breakwater*, Fig. 499, is situated just inside of Cape Henlopen, the southwestern point of land at the entrance of Delaware Bay, and was intended to form a harbor of refuge during storms for vessels passing along the coast. The work was begun in 1829. It consists of two parts, the breakwater proper and the ice-breaker. The former is 1,203 yards long, extending in an E. S. E. and W. N. W direction. The ice-breaker, designed to protect the harbor from floating ice brought down by the Delaware River, is 500 yards long, and lies in an E. by N. and W. by S. direction. There is a passage of 350 yards between it and the breakwater, the prolongation of which would pass near the centre of the ice-breaker. The work protects from the more dangerous winds an area of about 420 acres, having a depth of 3 to 6 fathoms, leaving a passage of about 1,000 yards in length between the shore and its landward extremity. The width of the structure is 175 feet at base and 30 feet at top, and it is composed of rough blocks of stone. The inner slope has an angle of 45°. The outer slope has an inclination of 3 base to 1 height to a depth of about 19 feet below the highest spring tides, and thence to the bottom of 45°.

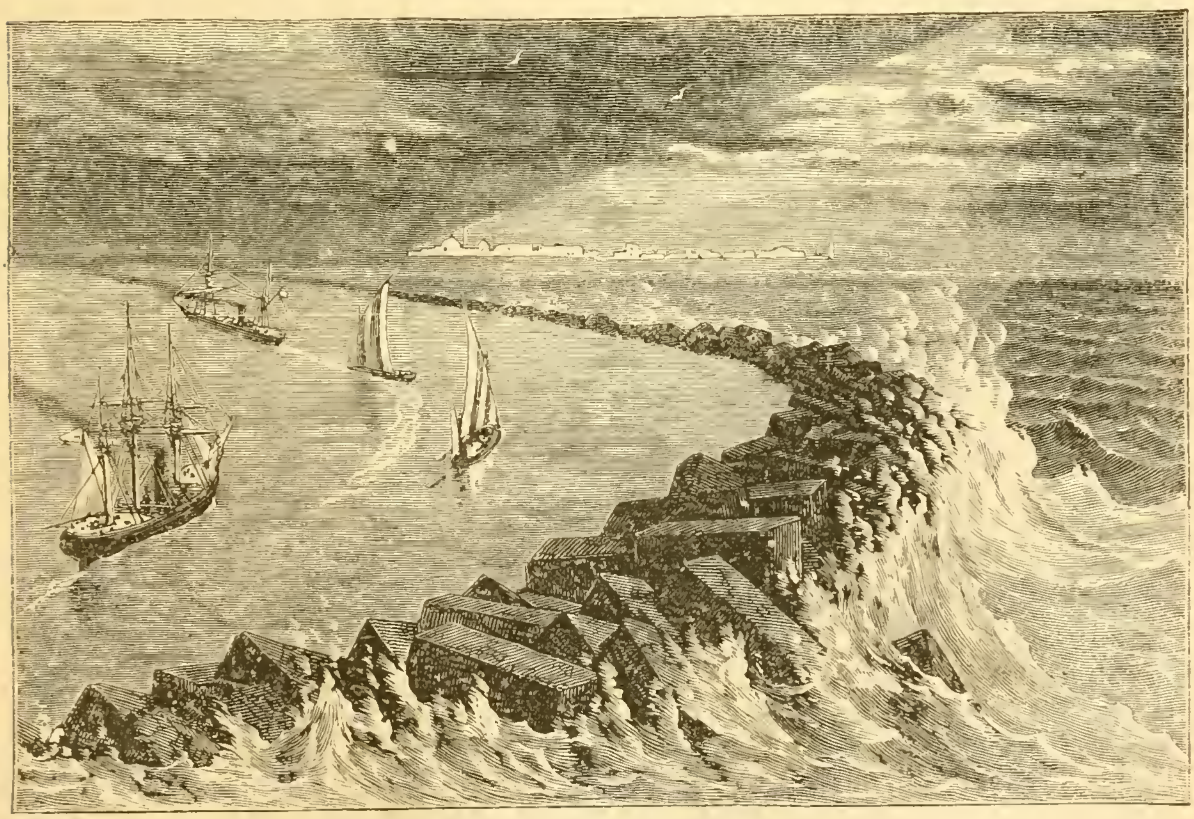
499.



*The South Breakwater, Aberdeen, Scotland.*—This breakwater is 1,050 feet long, and was completed in 1873. It is chiefly remarkable for the manner of its construction with liquid concrete. The foundation was laid with large bags of this material. The work was then carried up with concrete blocks of from 10 to 24 tons each to 1 foot above low water of ordinary neap-tides, from which level to the roadway, a height of 18 feet, it was formed entirely of liquid concrete deposited *in situ*. The composition of the liquid concrete was 1 part of cement to $2\frac{1}{2}$ of sand and $3\frac{1}{2}$ of gravel. The concrete blocks contained 1 part of cement to 3 of sand and 4 of gravel. The outer end of the breakwater was secured against the sea by dovetailing the concrete blocks into one another, and by erecting a tower of concrete 20 feet high on the end to add weight to it. Mr. W. Dyce Cay, in a paper on this breakwater (see *Engineering*, xviii., 491), expresses the opinion that concrete blocks, of the ordinary size of from 10 to 20 tons each, are not suitable for building a solid breakwater on sand or other soft material, and recommends that the parts of such a work below low water should be in blocks of from 100 to 200 tons weight each. He further considers that some of these blocks may with economy and advantage be deposited in a liquid state in bags. The cost of this breakwater was $370,000, or about $352 per running foot.

*The Manora Breakwater.*—This breakwater is located in the harbor of Kurrachee, India, and projects from Manora Point for a length of 1,503 feet into a depth of 5 fathoms of water in order to

500.



The Alexandria Breakwater.

shelter the entrance from the southwest monsoon seas, and to prevent their tearing up sand from the bottom and depositing it as a bar. The structure consists of a base of rubble-stone, leveled off generally to 15 feet under low water; and on this base concrete blocks, each weighing 27 tons, were

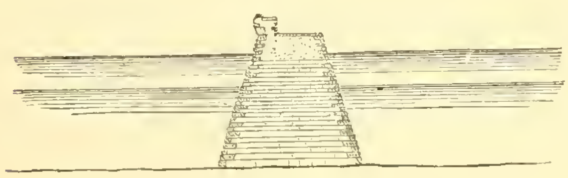
set on edge, leaning back at a slope of 3 inches to 1 foot, and without bond, two blocks forming the width and three the height, and together making a square of 24 feet in cross-section, the top being about the level of high water. The rubble base was deposited from native boats, and leveled for the superstructure by helmet divers. The materials composing the blocks were cement, river-sand, shingle, and quarry lumps, with salt water. The ratio of the bulk of the cement to that of the finished block was nearly one-eleventh. The blocks were sometimes used one month after being made, and once as an experiment a 27-ton block was safely lifted in seven days after compounding. This work was finished in February, 1873, and was about one year in building. Its total cost was $352,854, or about $234 per running foot. See *Engineering*, xx., 380; xi., 225; and xiii., 292.

Numerous other applications of concrete to the construction of breakwaters have been made. At Port Said, at the entrance of the Suez Canal, the two breakwaters, 3,390 and 1,968 yards long respectively, forming the harbor, were entirely built of Teil concrete blocks, 25,000 of these being required. At Alexandria, Egypt, the great breakwater, Fig. 500, 1½ mile long, is built with 35,000 Teil concrete blocks of the size above mentioned.

*The Azores Breakwater*, in process of construction, is intended to afford an artificial harbor of refuge opposite Ponta Delgada, St. Michael's. The principal work will consist of a mole attached to the land by natural rocks, crowned by a breakwater like that at Holyhead. This will be 2,821 feet in length at low water, and will shelter ships from the winds that blow from the S. E. and W. by S. The work has been in progress since 1864. The stone has had to be placed literally in the bed of the Atlantic. The material is a lava-stone quarried near by, and after being placed in position it is further strengthened by massive balks of timber bolted together by huge bars of iron. The estimated cost of the whole work is $2,676,000.

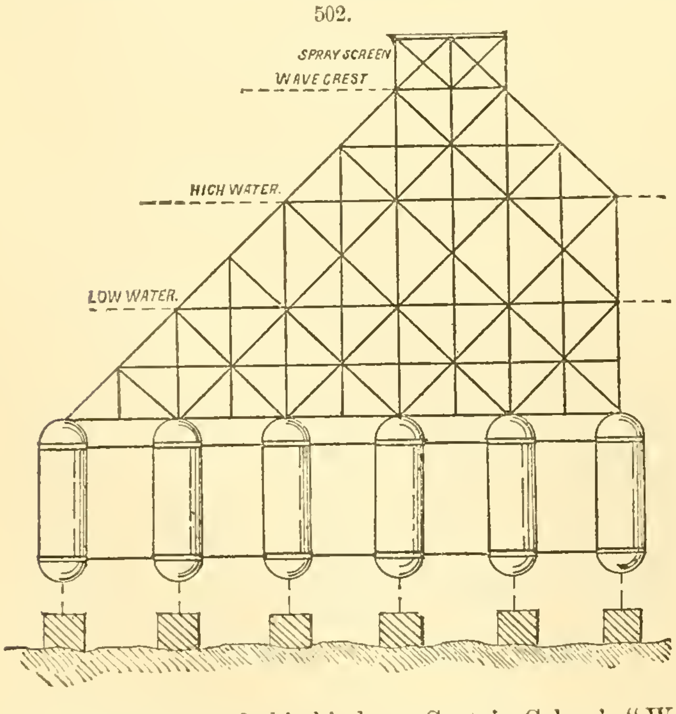
The new breakwater at Dover, England, Fig. 501, in process of construction, is formed by an outer and inner wall of ashlar masonry, with a course of granite on the face, and blocks of concrete made with Portland cement and shingle in the core of the work to the level of high water, above which it is filled with liquid concrete. The masonry commences from the chalk bottom of the bay, the blocks being placed by means of diving apparatus. Both the inner and outer walls deviate from a perpendicular about three inches to the foot, in steps. A parapet 15 feet above the level of high water surmounts the work on the sea side. All the operations are carried on from timber staging. The water at Dover is very deep, 42 feet at low tide, and the construction of the breakwater is upon the principle that the motion imparted by waves to water much below the surface is vertical, and that a vertical wall is best calculated to resist their action.

501.



*Various Forms of Breakwaters.*—Floating breakwaters have been proposed. One device consists of a wall of iron or other suitable material, which is to be placed vertically in the water, and to be of such a height that its lower edge will reach below the waves to comparatively calm water, while its upper edge will project above the surface sufficiently to form a breakwater. It is to be supported by water-tight compartments strengthened by girders and anchored to the bottom. When waves strike the top, it is claimed that the structure will yield only to a slight degree, owing to the great surface exposed to the still water on the opposite side, and the force of the waves will thus be checked. It is proposed to make the breakwater in sections 300 feet long by 60 feet deep, 44 feet of which will be under water, and each section to weigh 500 tons. See *Scientific American*, xxiii., 70.

502.




Another arrangement, proposed by Mr. Thomas Morris of London, is represented in Fig. 502. Here the heavy framework which breaks the force of the sea is supported on air-tight cylinders $A$, submerged in still water below the deepest wave, and anchored. The sloping screen $B$ is presented to the waves.

Floating breakwaters have not been favorably regarded by engineers. Mr. Scott Russell says concerning them: "No known force could effectively secure a large floating breakwater broadside on to a heavy ground swell. It would move horizontally with the wave of translation, which would propagate itself along the bottom just the same as if the breakwater were not there."

Isolated piles of timber or iron placed at certain distances apart have been proposed as breakwaters by Captains Calver, R. N., and Vetch, R. E. For a full description of structures of this kind see Captain Calver's "Wave Screen" (London, 1858), which contains much interesting information on the subject of harbors. Mr. Brunlees recommends a breakwater and pier of cast and wrought iron, the piles being placed zigzag at an angle of 90°, with the view of

increasing the strength of resistance. Mr. M. Scott has suggested a combination of horizontal wave-screens with a rubble base. See "Minutes of Institute of Civil Engineers" (British), 1860, p. 649.

*Lake Breakwaters.*—Breakwaters have been built on our northern lakes, which are made of a cribwork of strong timbers filled with stone. It has been found by experience that the cribs will keep in position better if the bottom is formed of latticework, sufficiently open to allow the stones to sift through when the crib is stirred by the waves. The cribs are usually made from 30 to 40 feet in width, from 60 to 80 feet in length, and of a depth suited to the depth of water. They are successively sunk and placed end to end and filled with stone until the work has attained the desired length. There being no tide in these lakes, the top of the crib need not be more than 8 or 10 feet above the mean water-level. Such breakwaters have been constructed at Buffalo on Lake Erie, at Oswego on Lake Ontario, at Plattsburgh and Burlington on Lake Champlain, and at other places. Aside from not possessing sufficient strength, these structures would not be practicable on the sea-coast on account of the destruction to which the timber would be exposed from attacks of marine worms; but in our fresh-water lakes this objection does not exist. If from any cause, however, the framework of the cribs should become weakened, new cribs can be placed on the inner or outer line of the first row, or on both sides, and thus a permanent stone foundation of rubble for a stone breakwater of the ordinary description may be gradually constructed.

The covering pier or breakwater of Buffalo Harbor is built of stone, and measures 1,452 feet in length. The top of the pier is 18 feet broad, and is 5 feet above the water-level. On the side of the roadway which is exposed to the lake, a parapet wall 5 feet high extends along the whole length of the pier, from the top of which a talus wall, battering at the rate of 1 perpendicular to 3 horizontal, slopes toward the lake. This sloping wall is formed of coursed pitching. Its foundations are secured by a double row of strong sheeting-piles driven into the bed of the lake, and a mass of rubble resting on the toe of the slope. The quay or inner side of the pier is perpendicular, and is sheathed with a row of sheeting-piles driven at intervals of about 5 feet apart from centre to centre, to prevent the wall from being damaged by vessels. The cost of the work was about $200,000.

*Works for Reference.*—The construction and history of many of the principal breakwaters are fully treated in the great work of Sir John Rennie, President of the Institution of Civil Engineers, upon British and foreign harbors, 2 vols., 1854. The most modern systems of breakwater construction and harbor improvements are discussed in Stevenson's "Design and Construction of Large Harbors," London, 1875. Details of construction of lake breakwaters and improvements of harbors in the United States appear in the reports of the Chief of Engineers U. S. A. for 1875, 1876, and 1877.

BRICK-MAKING MACHINERY. Bricks are masses of clay moulded commonly in rectangular blocks, baked, and employed for building purposes. American bricks vary in size in the different States, running from 7¾ to 8¼ inches in length, 4 to 4½ in width, and from 2¼ to 2½ in thickness. The weight is commonly reckoned at 4 lbs. to the brick, but this varies with the size, the amount of pressure to which the clay is subjected, and the heat applied in baking. English bricks are commonly 9 inches long, 4½ wide, and 2½ thick.

*Material.*—The best brick-clays are composed of silica three-fifths, alumina one-fifth, and the remaining fifth of iron, lime, magnesia, soda, potash, and water. Where there is an excess of alumina over the silica, the bricks are apt to crack in burning; the presence of silica remedies this by rendering the bricks more porous. Where sand is added to the clay it should be clean, sharp, fusible, and not too fine; proper selection and proportion insure a hard, strong, ringing brick of good color. For the finer grades of bricks, a finer sand may be used. Foundery sand ("fire-sand") is not at all suitable; good building-sand should be a proper material.

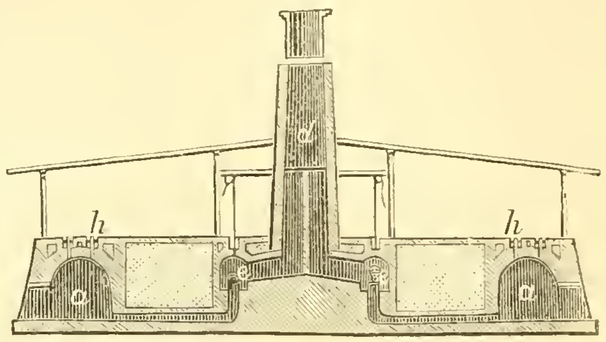
The quantity of sand or other substances required for any clay can only be determined by actual experiment. Sandy clay, or loam, and calcareous clay, or marl, are also used for brick-making; but if much lime be present the compound may be too fusible. Oxide of iron is rarely absent. In the process of burning it is converted into peroxide, and imparts to the whole brick its red color, more or less deep according to the degree of oxidation.

American clays, of course, vary somewhat. Those in Maine are light; in Massachusetts and Rhode Island they are more fatty. The Croton, Haverstraw, and other clays, on the Hudson River, are not of the best quality—containing an undesirable "quicksand," and being long in burning; besides which the bricks are likely to "whitewash" under the influence of weather. The Connecticut and Northern New Jersey clays resemble those of the Hudson. The belt extending along the eastern portion of Pennsylvania, down through parts of Delaware, Maryland, and the District of Columbia, is of the finest grade of loamy clay, producing bricks of the greatest hardness and cherry-red color; those of Baltimore being slightly the best in respect to the color of the finer grades. The brick-clay of Ohio and Indiana resembles that of Pennsylvania. The clay used in the vicinity of Chicago, being that obtained in excavating the "slips" in the rivers, is not only limy, but contains lime-pebbles, which renders it extremely difficult to work. In St. Louis the material is of loamy nature, with veins of what is called "joint-clay," which makes the bricks crack and check in drying and split in burning. The Milwaukee clay is of a plastic nature; it burns white, owing to the absence of iron. The Italian clays are plastic, and need no sanding. In France, the clays in the northern part are loamy and quite good, and about 2 metres deep; they gradually improve toward the southern portion. Cuban and South American clays are poor both in strength and color.

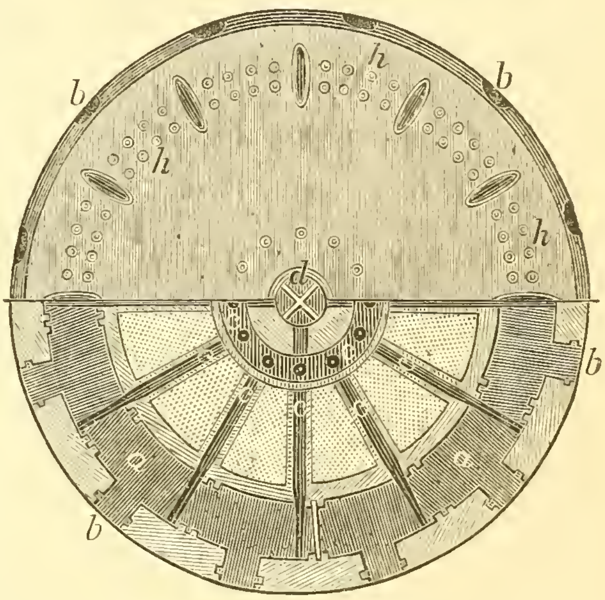
*Burning Brick.*—The annular furnace for burning brick, invented by Hoffman, Figs. 503 and 504, is extensively employed. A large annular chamber, with openings at the sides for the reception of the bricks, is constructed with a central chimney and with removable divisions for separating the annulus into different parts. When the furnace is filled with unburned bricks, heat is applied to one division, the smoke and hot air escaping into the adjoining one, which is the next to be burned, the air for maintaining combustion being received through the compartment last burned, whereby the

bricks in it are cooled. Each compartment of bricks or other articles is thus burned in turn, the waste heat of the burning compartment continually drying the compartment before it, and taking the heat of the one behind. The letters *a a*, Fig. 503, mark the circular arched furnace, having doors, *b b*. Flues, *c c*, lead to the circular chamber, *e c*, surrounding the chimney, *d*. Valves of cast-iron are made to close at pleasure the orifices of the flues. Movable sluices in the dividing walls allow of communication to be made or closed between the chambers; *h h* are plugs through which the coal, in powder, is introduced, undergoing calcination. The advantages of this furnace lie in its great economy of fuel.

503.




504.




*Fire-Brick.*—The following is condensed from a paper on "Refractory Materials," by Dr. T. Egleston, read before the American Institute of Mining Engineers, 1876. The materials of which fire-bricks are composed are generally fire-clays, which are hydrated silicates of alumina, containing from 50 to 65 per cent. of silica, 30 to 75 per cent. of alumina, and 11 to 15 per cent. of water. The clay contains (besides potash) soda, lime, magnesia, and iron, and is generally less refractory in proportion to the extent of these elements found in it. When it contains from 6 to 10 per cent. it will generally melt; when the clay is silicious, 3 or 4 per cent. of other substances make it fusible; when it is aluminous, 6 or 7 per cent. of oxide of iron does not make it lose its refractory qualities. The clay which, according to Brognaud, is most refractory when deprived of its hygrometric water, has the composition: Silica, 57.42; alumina, 42.58. Silica alone cannot be used without being ground, and, as it has no binding property like alumina, a small portion of binding material is added to it. For the Winas brick, which is the best substance to resist heat alone, this material is lime. The brick is made of quartzose sandstone, which is first heated in a furnace and then thrown into water to break it up, and is then ground. The amount of lime required to bind it together is $1\frac{1}{2}$ per cent., and the joints between the bricks are filled with the same material. At a temperature of 2,200° C.—about 4,280° Fahr.—these bricks will last four weeks in the roof of an ordinary furnace, and in that time will be reduced—by abrasion of the flame, and dust, and slightly from chipping—from 9 to 2 inches. The bricks conduct the heat so badly that, at this temperature, which is a bright white heat on the inside of the furnace, it is only just warm on the outside. Ordinarily, the bricks seem to be fluxed away by the dust, which circulates with the gases. In the Siemens furnace, where there is no dust, they give out from weakness.

Very few clays can be used as found. They must be, as it were, suspended in some infusible material, which will prevent, as far as possible, the mechanical effects of the heat, and allow, at the same time, of a certain amount of expansion and contraction, while preventing both in too great a degree. These materials are usually quartz-sand or pulverized quartz, burnt clay, old bricks, serpentines, talc, graphite in powder, and not infrequently small coke, when the ash is not to be feared, and when graphite either cannot be had, or cannot be used on account of its high price. When the mixture is made in the place where it is to be used, without previous burning, it is generally made of one-fifth plastic clay and four-fifths burned clay or quartz, or one-fourth lean clay and three-fourths burnt clay or quartz. This is done to avoid contraction. It is a most economical construction, even in blast-furnaces, and is coming more and more into use.

The clay, when mined, is left exposed to the air under sheds, and is cleaned and carefully dried, and is afterward mixed with the substances with which it is to be incorporated, which are classified by numbers, varying according to the size of the sieve-holes through which they will pass. The quantity and quality of the mixture will determine the refractory nature of the material to be produced. A friable paste with large grains and quite porous resists a great heat. One with fine grains, close and compact, splits at a high heat, especially if it is not homogeneous. The manner in which the mixture is made also influences the quality of the brick quite as much as the material. In some works in Belgium, after taking all the ordinary precautions to make the mixture perfect, it is submitted to a succession of shocks continued for some time, until it is found by experiment that the materials are perfectly mixed. It has been found by long experience that the bricks so made kept their form perfectly, while others, made of exactly the same mixture in the ordinary way, contract.

The paste made and the article completed, it must be dried or "tempered." This is commenced in the open air, and, if possible, out of the draught. If the draught cannot be excluded, the place where the drying takes place is slightly heated, commencing at a temperature from 60° to 70° Fahr., and keeping it up from 25 to 30 days, then increasing it from 80° to 100°, leaving the article as long as

possible, and so on, an active ventilation, but the same temperature, being kept up. The article should remain in a temperature of from 150° to 180° for at least 6 weeks. Bricks do not generally require so much care; but crucibles and retorts do. Long experience has proved that there is a great economy in conducting this process of tempering as slowly as possible, and that it influences materially the refractory nature of the article. It is found, by actual experiment in crucible works, that those crucibles made from the same mixture, tempered during 6 to 8 months, last more than three times as long as those which had been tempered only 2; so that, in general, the older the article before being burned the better.

The essential qualities of a good brick may be stated as follows:

1. Uniformity.
2. Regularity of shape, and the power to retain it under all circumstances, which involves perfect unity of composition.
3. Strength to resist the different pressures required under different circumstances.
4. Its cheap price.

No material yet manufactured entirely fulfills all these conditions. A good brick should not only resist high temperatures, but sudden changes of temperature, without alteration of any kind, such as crushing, splitting, etc., and, at a high temperature, should undergo the least possible change of form. In general, it may be said that bricks which have undergone a very high temperature in the manufacture are less likely to contract afterward. Shrinkage is generally due to insufficient burning, or to a too small proportion of old material in the mixture, and generally occurs in aluminous bricks. Its chief evil is in allowing the flame to penetrate the open joints, and give the dust an opportunity to cut between the bricks; for any cause which produces eddies in the flames, such as hollows or projecting surfaces, is certain to effect the destruction of that part of the furnace. Silicious bricks have, on the contrary, a tendency to expand under the influence of intense heat. This is true to such an extent that, in the steel furnace where they are used, provision must be made for slackening the tie-rods when the fire is being raised, and tightening them when it is being cooled.

The crushing weight of an ordinary fire-brick, cold, is from 600 to 1,000 lbs., but some of the best have been known to resist as high as 3,000 lbs. to the square inch. To insure the safety of the structure and the success of the process, it should not only retain its power of resistance, but should not undergo any change of form nor soften materially under long-continued heat, and, at the highest possible temperature, should support more than double the strain required without attention. In the walls of the fireplace those bricks will be best which are dense, and contain an excess of silica. In the hearth they should contain an excess of alumina. In the arch they should be nearly pure silica, alumina, or magnesia. Bricks in a roof give out from shrinkage, cracking, or splintering. Splintering takes place when silicate bricks are made of impure mixtures, usually from too much fine material and from imperfect burning. Bricks which are liable to splinter are generally cross-grained and dense, with a smooth conchoidal fracture when made from improper mixtures, and when from bad burning they generally ring like a cracked vessel. All good bricks wear off evenly.

Decay of Bricks.—Dr. John C. Draper has investigated the causes of decay in brick and stone, and determines the same to be:

1. Roughness of surface favoring the deposition of dust.
2. Vegetable growths favored by dust and moisture.
3. Percolation of water through interstices and fissures.
4. Action of frost.
5. Action of acid vapors in the air.

The disintegration due to frost he finds to equal a loss of substance of 74 parts in 10,000 for red and 24 parts for white brick, or in the ratio of 1 for the latter to 3 for the former. The friability due to heating and sudden chill causes a loss of substance of 82 parts in 10,000 for red and 43 parts for white brick, which gives a ratio of 1 for the white brick to 2 for the red. The chemical ingredients of air that act on building materials are carbonic, nitric, sulphuric, and sulphurous acids. On subjecting bricks to the action of these acids a loss of 33 parts of substance per 10,000 for red and 7 parts for white brick was noted. Ratio of disintegration, for white 1, for red 5. Evidence is thus afforded of the resisting power of hard, compact brick.

The absorbent capacity of bricks, according to the report of an English committee, is indicated by the following table:

*Average Taking up of Water by Bricks set in a Depth of Water of Three-fourths of an Inch.*

| SPECIMENS OF BRICK. | Contents in Cubic Inches. | PERCENTAGE OF SATURATION. | | | |
|---|---|---|---|---|---|
| | | In ¼ Hour. | In ½ Hour. | In 2½ Hours. | In 14 Hours. |
| No. 1.—Best made by hand, which absorbed 15 inches of water in all | 100′ 6″ | 44 | 56 | 70.6 | 100 |
| No. 2.—Manufactured brick, absorbing 35 in all | 136′ 4″ | 30 | 55 | 85 | 100 |
| No. 3.—Same, absorbing 21 | 117′ | 41 | 75 | 98 | 100 |
| No. 4.—Same, pickled 38 hours, and absorbing in all 14.3 cubic inches of water | 111′ 41″ | 33 | 36.4 | 50 | 75.7 |
| No. 5.—Good hand-made brick, absorbing 14 | 95′ 6″ | 47 | 59 | 68.75 | 90.5 |
| No. 6.—Same, absorbing 25.6 | 100′ 4″ | 40.75 | 64.4 | 95 | 98.4 |

The capacity of several of the specimens to give off the moisture absorbed, at a given temperature, is represented in the following table, in which the drying of the six bricks adduced in the foregoing table was annotated in all its features:

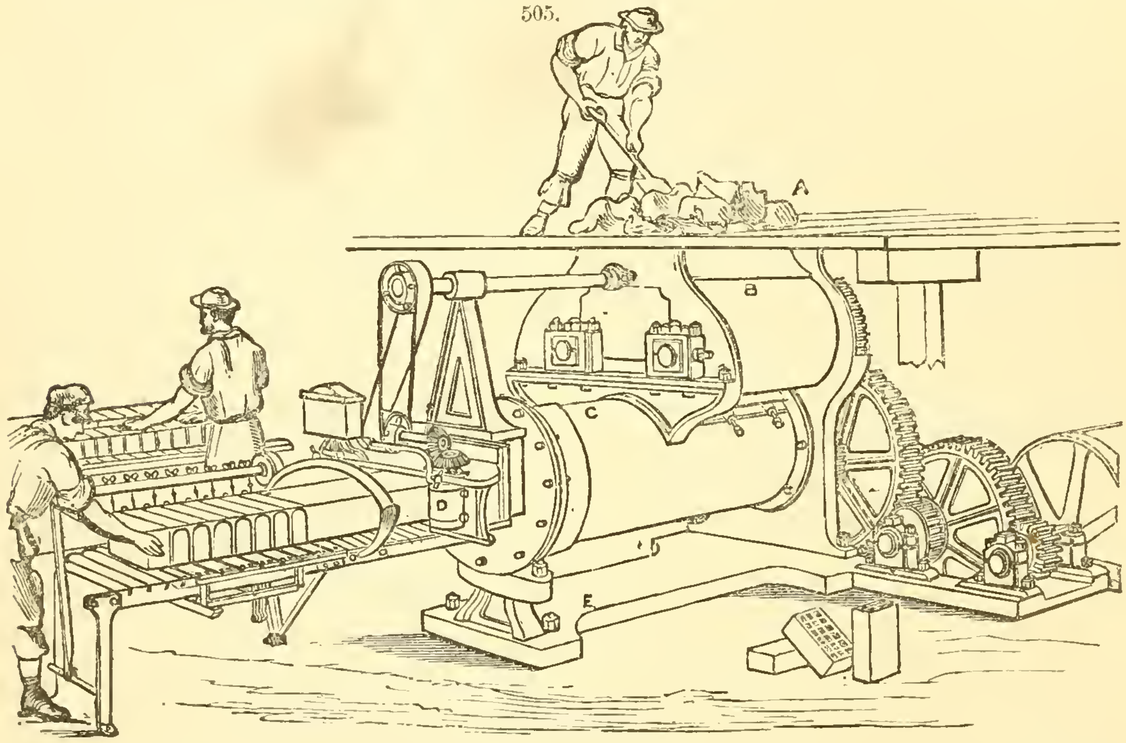
*Table showing the Capacity of Bricks to give off Moisture.*

| NUMBER. | Water in Cubic Inches. | TEMPERATURE, 35.2° FAHR.—PERCENTAGE OF WATER GIVEN OFF. | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Hours, 4¼. | Day, 1. | Days, 2. | Days, 3. | Days, 4. | Days, 5. | Days, 6. | Days, 11. |
| 1 | 15 | 8.57 | 42 | 68.6 | 78 | 81 | 82.9 | .... | 94.3 |
| 2 | 35 | 8.5 | 32.1 | 50.6 | 69.1 | 81.4 | 86.4 | 90.1 | 96.3 |
| 3 | 21 | 4 | 34.7 | 61.2 | 75.5 | 81.6 | 85.6 | 89.8 | 96 |
| 4 | 44 3 | ..... | 50 | 63.6 | 72.7 | 76.4 | 78 | 82 | 82 |
| 6 | 25.6 | 3.4 | 30.5 | 54.2 | 74.6 | 81.3 | 86.4 | 89.8 | 91.5 |

Brick Machines, for the mechanical moulding of plastic clay, are so exceedingly numerous that it is impossible in the limits at present disposal to convey to the reader other than a general idea of the more prominent types. Many not here represented will be found described in Reports of Judges of Group II., Centennial Exposition. The following examples are classified in the manner proposed by Mr. E. H. Knight.

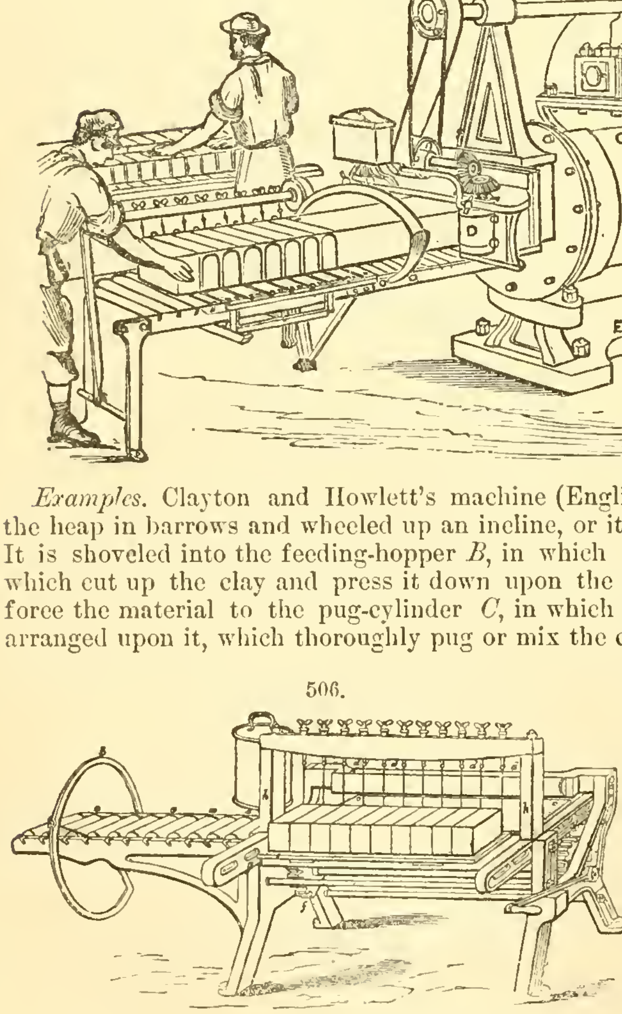
Class I. Those machines in which a slab of clay exudes from the pug-mill, and is cut up into lengths which form bricks. The cutter is a wire or knife, and either travels with the slab while cutting, or makes a square transverse cut across the moving slab.

505.




*Examples.* Clayton and Howlett's machine (English), Fig. 505. The rough clay *A* is taken from the heap in barrows and wheeled up an incline, or it is drawn up the incline by suitable mechanism. It is shoveled into the feeding-hopper *B*, in which revolves a shaft carrying several small knives, which cut up the clay and press it down upon the rollers incased in *B*. The crushing-rollers then force the material to the pug-cylinder *C*, in which revolves a strong shaft, having knives spirally arranged upon it, which thoroughly pug or mix the clay and at the same time force the homogeneous mass toward the end *D* of the cylinder, where it passes through the moulding orifice to the cutting-off table, shown separately in Fig. 506. When a stream of clay sufficient to cut the desired number of bricks has been expressed upon the receiving-rollers *a*, a single cutting-wire *b* divides the mass.

506.

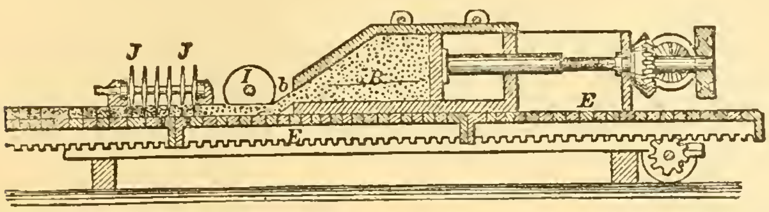


The portion thus removed is drawn forward by hand to the table *c* in front of the wires *d*, and the stream from the machine is again allowed to escape and again cut off, the operation thus being rendered continuous. In order to cut the separated section into bricks, the wires are caused to pass through it by operating the handle *e*, which simultaneously transmits motion to the pinions *f*, the racks *g*, and the whole rack-frame *h*, carrying with them the series of wires *d*, and also the plate-table *c* and platen *i*, causing the plate-table *c* to pass from under the clay through which the wires are passing, and to be replaced by the portable platen *i*. Another movement of the handle returns the parts to their original position and the platen with the now formed bricks upon it is removed.

In the Tiffany wet-clay machine (Canadian) the impelling screw-shaft revolves in an opposite

direction from the tempering-screw; its shaft passing through that of the latter, which is hollow. The bar of clay issues upon a bed of rollers, and is cut into bricks by four wires fixed in an oscillatory frame. Fig. 507 represents a machine in which the tempering-device is separate, the impelling-worm being replaced by a piston fitting tightly in the reservoir *B*, and driven by a screw and bevel gearing. The clay issues in a slab *b* of the width of a brick, which is cut by disks *I* into ribbons as wide as the length of a brick. These last are cut into blocks by disks *J* (spaced apart the width of a brick) borne on a mandrel whose bearings are in a carriage moving transversely in ways. The bed is made in sections *E*, which are passed along in succession by rack and pinion.

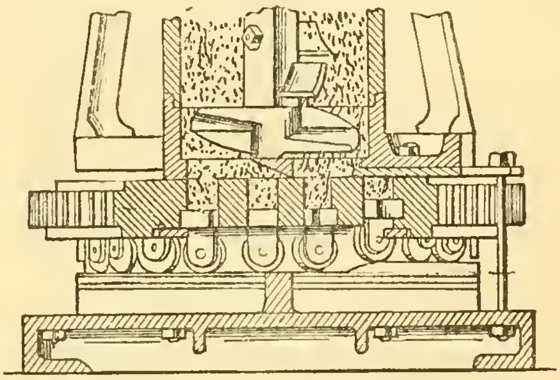
507.




Class II. Those in which the clay passes from the pug-mill into moulds in which it is pressed, and from which the moulded brick is discharged.

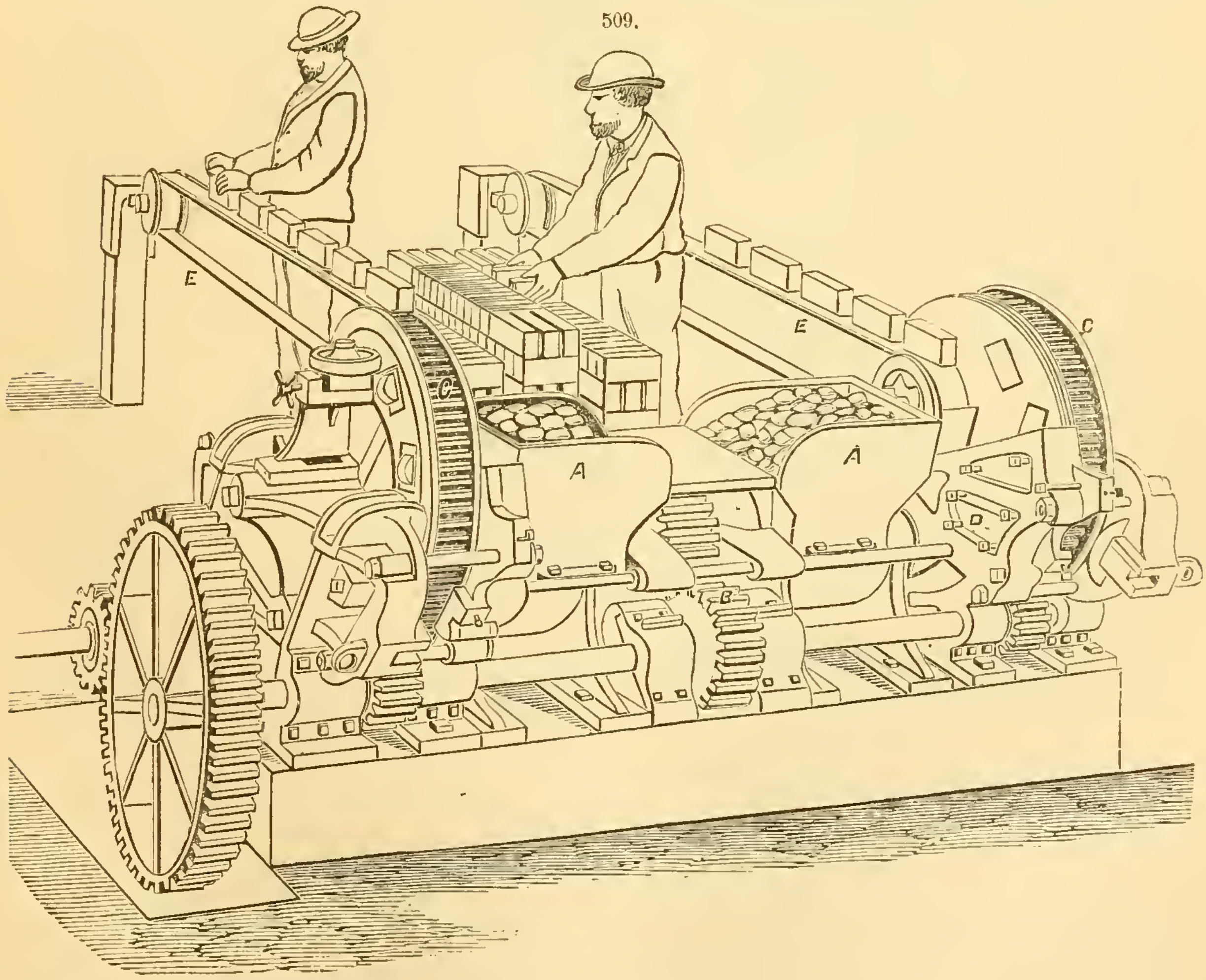
*Variety* 1. Machines in which the moulds are on the upper or adjacent surface of a mould-wheel revolving in an horizontal or vertical plane, the moulds being brought successively below or in face of the pug-mill by which they are charged. In one case the pug-mill is vertical, in the other horizontal.

508.



The machine shown in Fig. 508 has a vertical pug-mill in which the clay is tempered and mixed, and is forced therefrom into moulds wherein it is pressed by an S-shaped spiral wiper. The pistons with their wheels and the inclined track below them are represented. A triple pressure-machine is manufactured, in which the charge of each mould-table is first leveled off with a straight edge, then successively compacted by a roller, compressed with a toggled piston and follower from below, and by cams and toggles above. Any variation in

509.



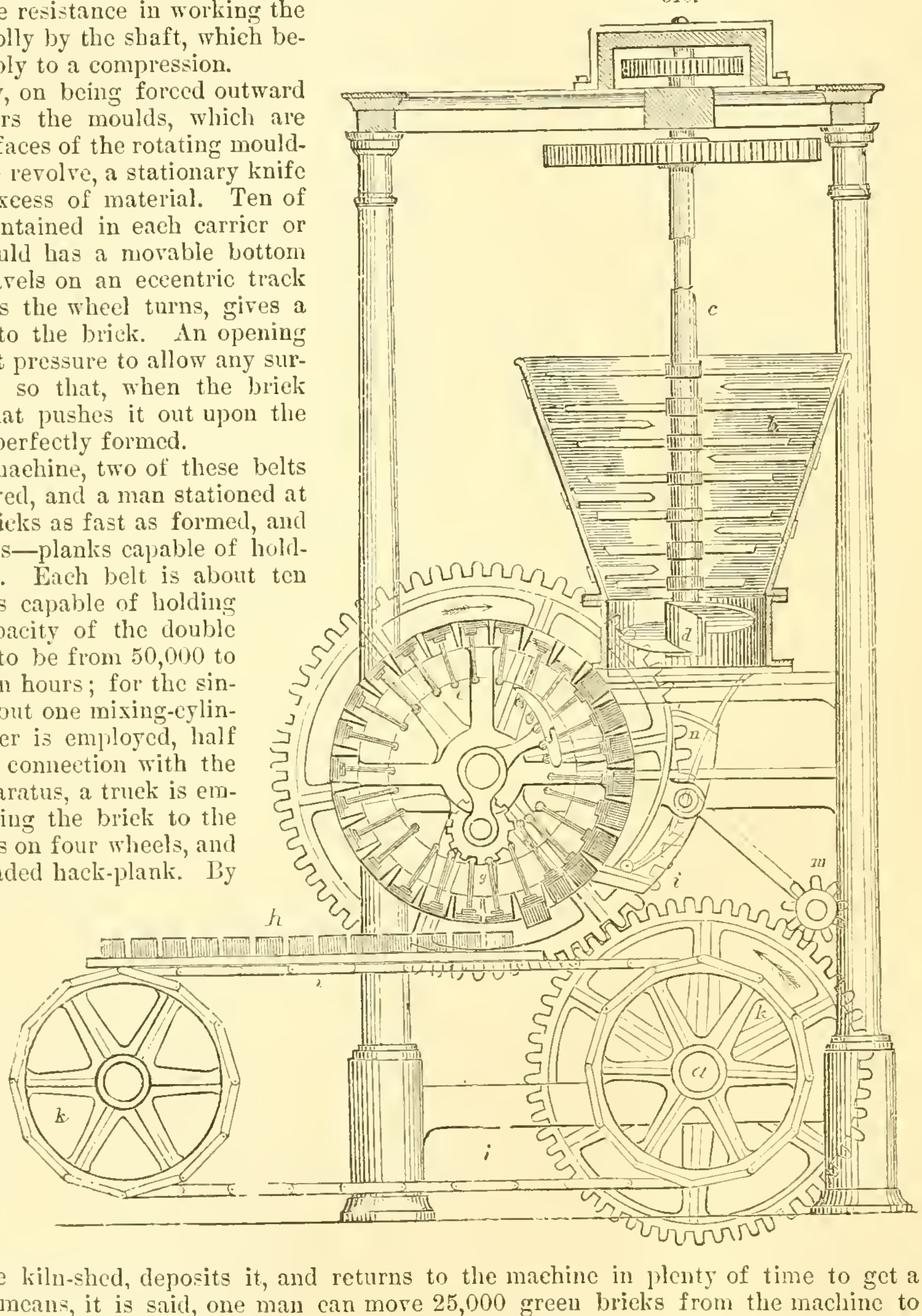

thickness is prevented by sinking a panel in one face, any deficit of clay simply permitting the sinking of a deeper panel, and not affecting the thickness of the brick. This is a crude clay-machine. A so-called impact machine has moulds in groups of four each. These have plunger bottoms, and

the first pressure is given by the blow of a weighted plunger. Repressure is effected by cams, and the discharge by the followers ascending an inclined plane. This is a dry-clay machine.

The Imperial brick-machine, Fig. 509, is an example of the horizontal pug-mill and vertical mould-wheel type. The apparatus, as here illustrated, is double—two machines in one—which produce a proportionately greater quantity of bricks.

The clay is thrown into the two hoppers *A*, and descends into the horizontal mixing-cylinders below. Of these there are two, and through both passes a 6½-inch wrought-iron shaft, actuated by the gearing shown at *B*. In each cylinder, and on the shaft, are steel cutters, and also screws, the latter adjusted in relatively reverse directions, so that the clay is thus forced out of the outer ends of both cylinders at once; and at the same time the thrust due to the resistance in working the clay is sustained wholly by the shaft, which becomes subjected simply to a compression.

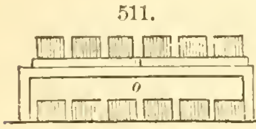
510.




The tempered clay, on being forced outward by the screws, enters the moulds, which are formed in the inner faces of the rotating mould-carriers *C*. As these revolve, a stationary knife at *D* removes any excess of material. Ten of these moulds are contained in each carrier or wheel, and each mould has a movable bottom with a roller that travels on an eccentric track beneath it. This, as the wheel turns, gives a series of pressures to the brick. An opening is left before the last pressure to allow any surplus clay to escape, so that, when the brick comes to the cam that pushes it out upon the endless belt *E*, it is perfectly formed.

With the double machine, two of these belts are of course employed, and a man stationed at each removes the bricks as fast as formed, and places them on hacks—planks capable of holding 500 bricks each. Each belt is about ten feet in length, and is capable of holding 11 bricks. The capacity of the double machine is claimed to be from 50,000 to 60,000 bricks per ten hours; for the single machine, where but one mixing-cylinder and mould-carrier is employed, half that aggregate. In connection with the above-described apparatus, a truck is employed for transporting the brick to the drying-yard. It runs on four wheels, and is brought over a loaded hack-plank. By means of a crank and simple mechanism, the latter, with its load, is lifted, and suitable tracks being provided, the truck can be moved off by one man to any desired point, where the hack is deposited. He then takes a hack-plank of dried brick to the setter (in the same way) under the kiln-shed, deposits it, and returns to the machine in plenty of time to get a new load. By this means, it is said, one man can move 25,000 green bricks from the machine to the yard, and take therefrom 25,000 dry bricks to the setter, in one day. The other hands required for operating the machine are two men to shovel in clay, and two to remove and hack the brick.

511.

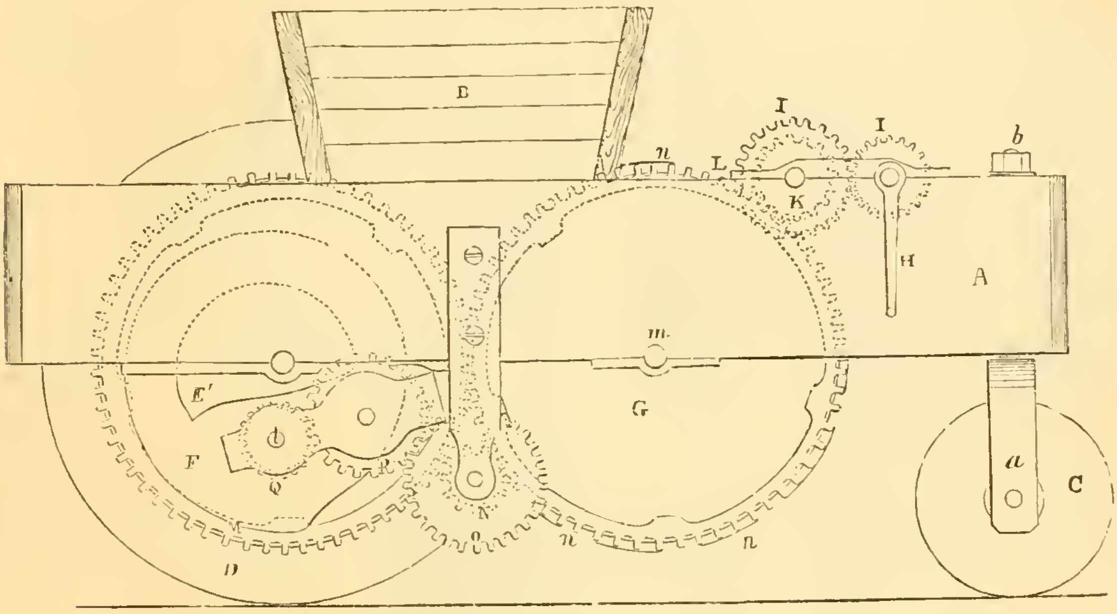


*Variety* 2. Those in which the moulds are on the periphery of a wheel, and receive their charge from a pug-mill or hopper above. The clay in the mould is pressed by the application of interior or exterior force, or both, and the moulded bricks are discharged by a piston-follower.

In Leahy's machine of this description, illustrated in Figs. 510 and 511, *a* is the main horizontal shaft in direct communication with the steam-engine or other first mover; *b* is a hopper-formed vessel, technically termed the pug-mill, in which the clay and other materials are tempered and mixed up: it is for this purpose furnished with cross iron bars, or blades of steel; part of these are firmly fixed to the *hollow* vertical shaft *c*, and the remainder bolted to the sides of the pug-mill, and they are so arranged that those fixed to the shaft cut in as they revolve between the others. The clay is delivered into the hopper or pug-mill by an endless chain of buckets (in the same manner as ballast

is raised); it is then cut up and tempered by the knives and bars in the pug-mill; and gradually descending, it falls, or rather is forced by the superincumbent pressure, upon the circular inclined plane *d*, which consists of a single thread or spiral turn of a very large screw, occupying the whole internal space of the lower cylindrical end of the mill, where it is exhibited in section. This screw or circular inclined plane is fixed to the central shaft passing longitudinally through the hollow shaft, and a slow reversed motion is given to it by means of an intermediate wheel acting upon pinions in the upper part of the frame. The blades on the hollow shaft revolve in the pug-mill at the rate of 15 turns in a minute, grinding and dividing the materials, which are forced upon the circular inclined plane of the screw; and as this slowly revolves in a contrary direction at the rate of five turns in a minute,

512.

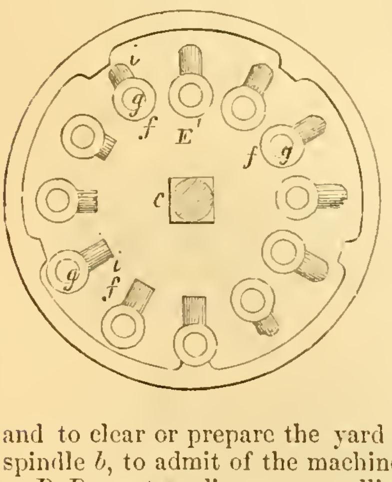



it forces the clay out of the mill, in a very compact state, into a receptacle below: of this, one side is always in immediate contact with the moulds, and those two sides which are at right angles to the former side are closed by iron cheeks, between which the lever or forcing flap *n* acts by pressure, and, fitting closely, prevents the escape of the clay, so that it can only pass into the moulds. These moulds are placed round the periphery of a circular frame *c*, made of flat iron rings, fixed upon bars or spokes, and turning upon a *fixed* shaft. There are 25 of these moulding-boxes in one circle. Each moulding-box is furnished with a false or movable bottom, to which rods are attached, for the purpose of pushing out the brick when moulded, and drawing back the bottom to its place to receive a fresh portion of the clay.

In Joseph Grant's rotary and locomotive machine, represented in Figs. 512 to 516, there are two cylinders set horizontally in a framing and revolving in opposite directions, being driven by gearing, which also propels the machine forward as the brick is being made.

One of these cylinders is fitted with moulds, working in which are followers, forming the bottom of the moulds, and operated by rollers moving in fixed grooved channels, and by cams producing the drop-motion. The second or pressing cylinder is provided with plates working and fitting into the moulds of the other cylinder, pressing the clay, which is fed from a hopper above and between the two cylinders, the clay being drawn into the several moulds by its own weight and the revolving motion of the cylinders, and the bricks deposited on the ground or surface prepared for them, in regular layers or line, as the machine moves forward; a roller in front clears or prepares the ground or surface on which the bricks are to lie. The followers in the moulds are covered with cloth or similar material to prevent the clay or soft bricks from adhering to them—the machine being worked by hand or other power.

513.




To enable others skilled in the art to make and use this invention, the inventor describes its construction and operation as follows:

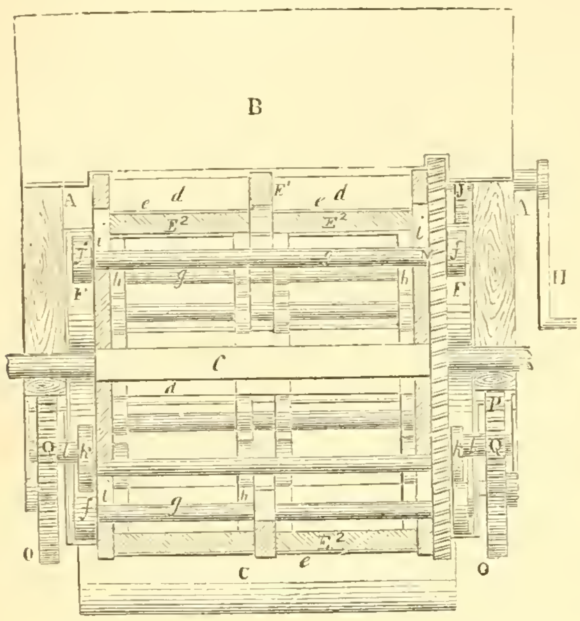
*A A* is the frame of the machine; *B*, the hopper through which the clay is fed; *C*, a leveling-roller, serving to carry the machine and to clear or prepare the yard for deposit of the bricks; it works in a strap *a*, having a swivel-spindle *b*, to admit of the machine being moved about in any direction.

*D D* are traveling or propelling wheels fitted on the mould-cylinder shaft *c* and turning with it. *E'* is the mould-cylinder keyed fast to the shaft *c*; it is made of iron or other suitable material, and has on its circumference or surface spaces *d d d* forming the moulds. The number of moulds is not limited to two rows, as shown in the drawing, but will be dependent upon the length of the cylinders as well as the diameter; each mould or space *d d d* being only of the length of the brick, so that the machine may, if required, be constructed to form three or more layers.

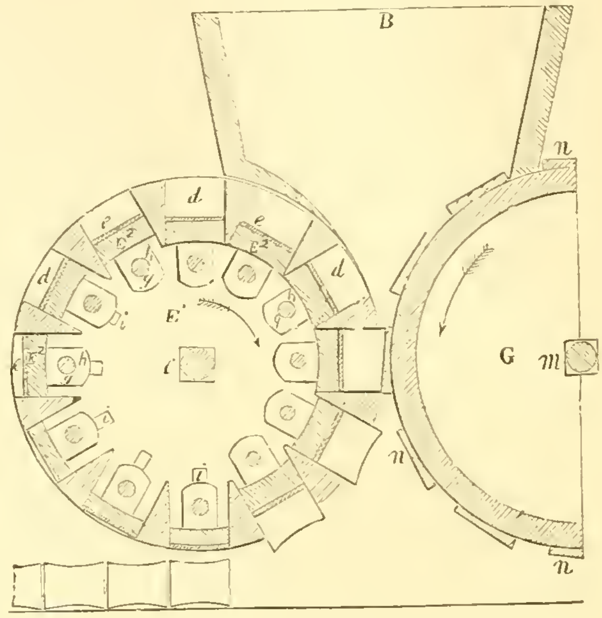
$E^2E^2E^2$ are followers, or plungers, working in and forming the bottom of the mould; they are

covered on their top with fine cloth *e e e*, and are of length and breadth so as to fit loose in the moulds *d d d* in which they move, motion being given to them by rollers *f f f*, which turn on spindles *g g g* running through the cylinder $E'$ lengthwise, passing through slots *i i i* at both ends; the

514.

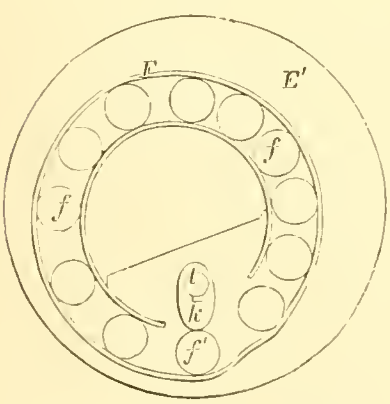


515.



spindles *g g g* are connected to the followers $E^2$ $E^2$ $E^2$ by pieces *h h h* attached to them, through which the spindles *g g g* pass, the rollers *f f f*, as the cylinder $E'$ is caused to revolve, moving in fixed grooved channels *F F* secured to the framing *A A*, the interior of one of which is seen in

516.



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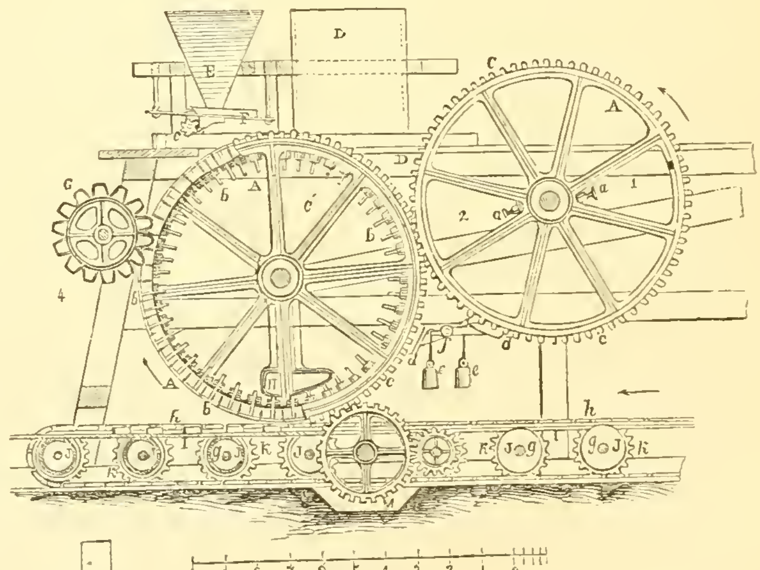
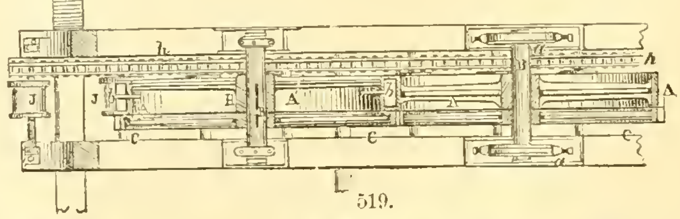


518.



519.

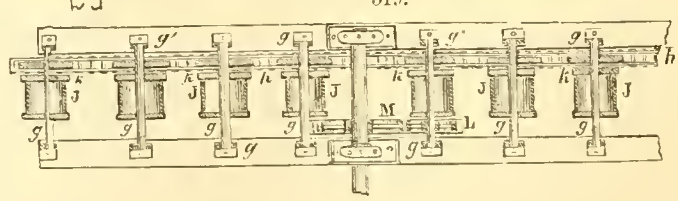


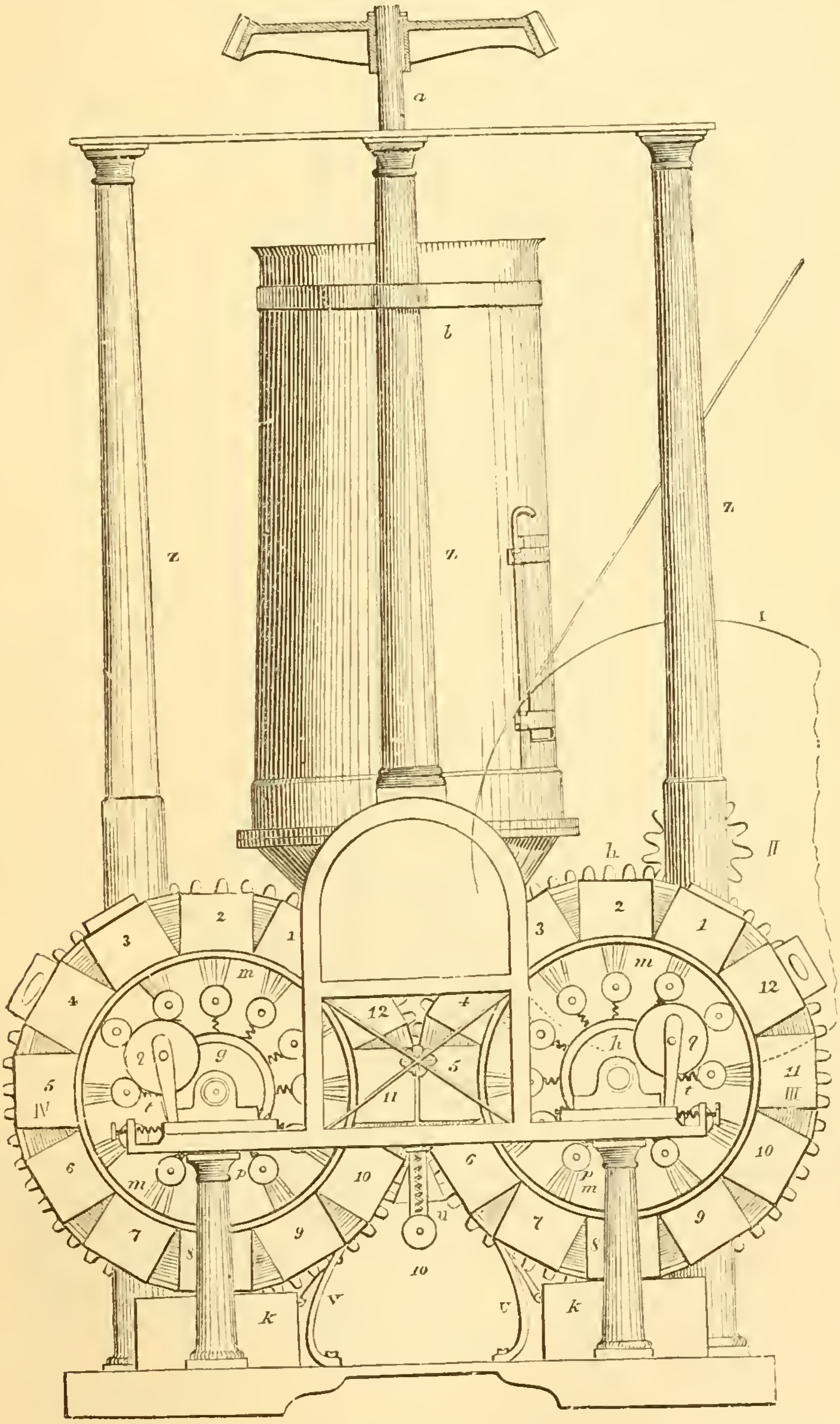
Fig. 516, being positioned with relation to the cylinder $E'$ in the manner of an eccentric, one at either end, but differing from an eccentric in their being made of a scroll or irregular curve formation. The rollers *f f f*, traveling in the grooved channels *F F*, cause the followers $E^2$ $E^2$ $E^2$ to move in the moulds *d d d*, the followers at their bottom stroke leaving a space in the mould equal to or rather exceeding the thickness of a brick, and, when forced out, working nearly to the outer edge of the moulds *k k*.

In Fig. 516 are represented cams attached to shafts *l l*, and so positioned and set as to perform as many revolutions for one revolution of the cylinder $E'$ as there are moulds in a single row, causing the cams *k k*, one at either end, to strike the rollers *f f f*, two together, that is, one at either end, and so on for all the rollers successively as they assume the position of $f'$, Fig. 516, causing the formed bricks to be shaken from their moulds when arriving at a perpendicular position. The bottom of the mould-cylinder $E'$ is situated rather more than the thickness of a brick from the ground or yard surface.

$G$ is the pressing cylinder revolving in the opposite direction to the cylinder $E'$; it is keyed on the shaft $m$. $n\,n\,n$ are pressing plates fitted on the circumference or surface of the cylinder $G$, corresponding to the spaces or moulds $d\,d\,d$ in the cylinder $E'$, into which they fit or press the clay; they are made thicker at the edge first entering the mould than the finishing or after edge, as shown more particularly in Fig. 515.

$H$ is a handle for giving motion to the machine (but the arrangement may be such that steam or other power may be applied). $I$ is a pinion turned by handle $H$; it operates a wheel $J$, on the shaft

520.



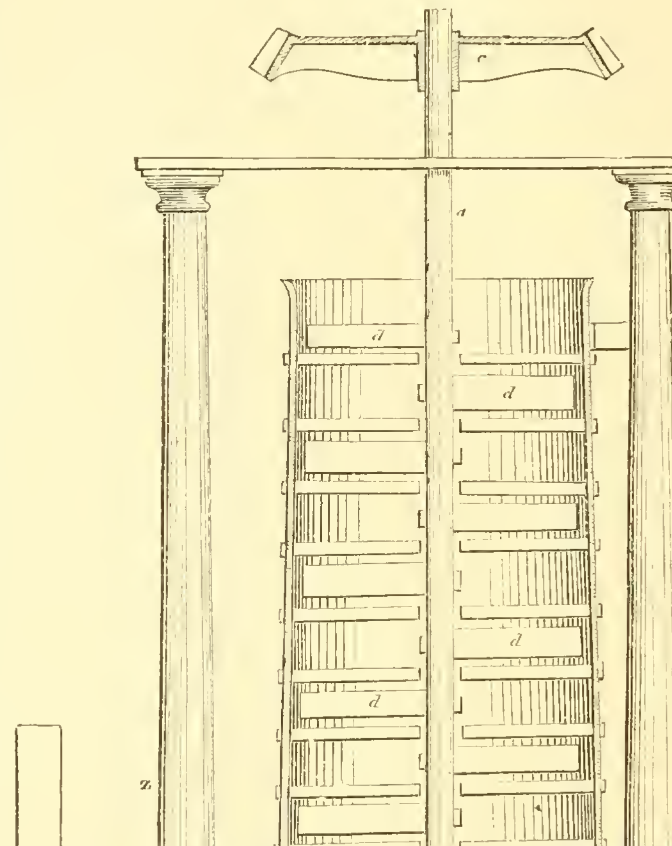
of which is a pinion $K$ working into a wheel $L$ fitted fast to the side of the cylinder $G$; the wheel $L$ is in gear with a corresponding wheel $M$ attached to the cylinder $E'$; the wheel $L$ also drives a pinion $N$, on the shaft of which are wheels $O\ O$, one at either end, working into similar wheels $P\ P$ that drive pinions $Q\ Q$ fitted on the cam-shafts $l\,l$, which they operate. The relative proportions of these several wheels and pinions are such as not only to obtain additional power, but to operate the drop-motion formed by the cams $k\ k$ at a proper time—that is, to strike the rollers when they assume the position of $f'$, Fig. 516, so as to release the brick, and likewise to operate the propelling or traveling wheels, which are of a suitable relative diameter, so that the machine will move at a speed proportioned to the discharge of brick, causing the bricks made to be deposited regularly, side by side, in layers.

The operation is as follows: Clay being put into the hopper *B*, the handle *H* is made to turn, and by wheels and pinions *I*, *J*, *K*, *L*, and *M*, the cylinders *E′ G* are made to revolve in opposite directions, as shown by arrows in Fig. 515, drawing the clay, partly forced by its own weight, into the moulds *d d d;* the pressing plates *n n n*, entering the moulds at their thick edge first, press and, together with the moulds, form the brick; the plates *n n n* leaving the moulds at their thin edge obviates the tendency which the soft brick has of being pressed thinner at the side or edge receiving the last or latest impression. While the cylinders *E′ G* are performing this operation, the machine, through means of the propelling wheels *D D*, is moving forward, and the several followers or plungers $E^2$ $E^2$ $E^2$ are being worked by means of the rollers *f f f* traveling in the fixed grooved channels *F F*, which causes the followers or plungers $E^2$ $E^2$ $E^2$ to draw in for receiving the clay, and when the brick is made to be forced out, and so drive out the brick, which is further released from the mould by the action of the cams *k k*, driven by the gearing *N O O P P Q Q*, the cams *k k* striking the rollers *f f f* when arriving in the position of *f′*, Fig. 516, and dropping or shaking the brick from the followers, which, being covered with fine cloth or other similar material, are not so liable to retain or cause the soft brick to adhere. The bricks are laid in the yard side by side and in perfect layers, in the manner shown in Fig. 515, the number of layers being dependent upon the size of the machine or length of the cylinders *E′ G*, which may have one, two, three, or more rows of moulds or pressing plates.

Capouillet's machine, also on this principle, is represented in Figs. 517 to 519. This machine consists of two cast-iron cylinders, performing the office of rollers. One is perfectly smooth, the other is pierced over all its surface with cavities, the size of which depends on the size of the bricks to be made. Pistons are made to fit into these cavities. These pistons receive an alternate movement equal to the thickness of a brick.

*Variety* 3. Those in which two wheels are provided with peripheral moulds, which are charged with clay from a hopper above, and in which the pressure is derived in whole or in part from the contact of the peripheries of the wheels with each other.

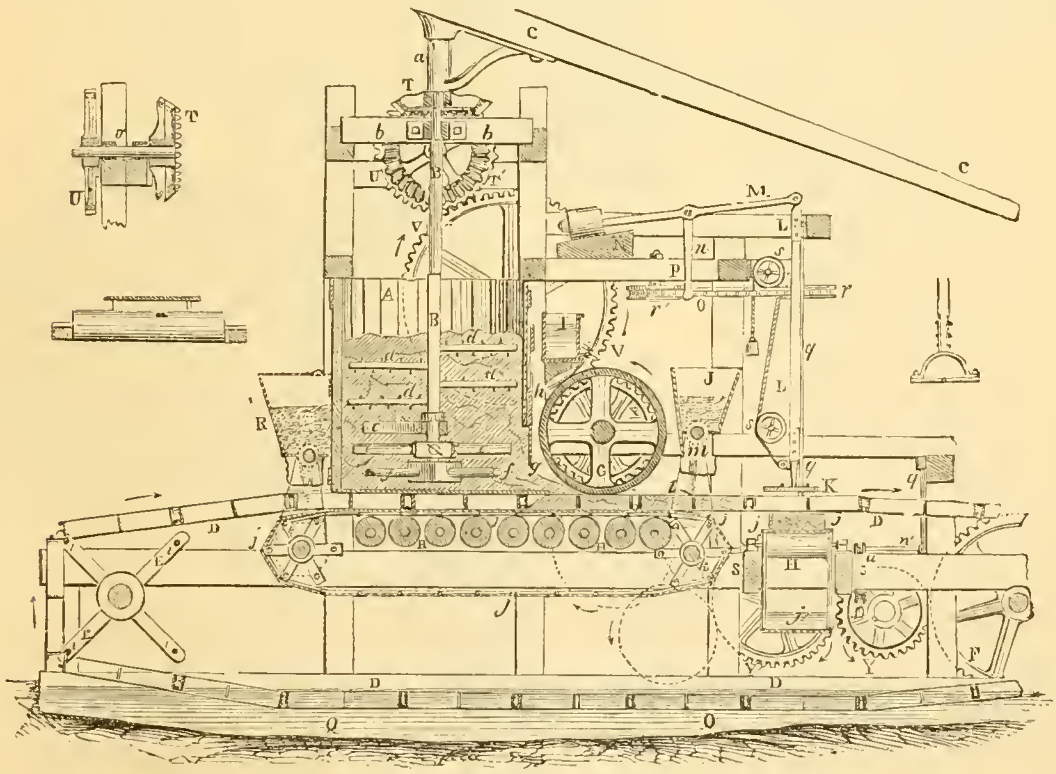
521.



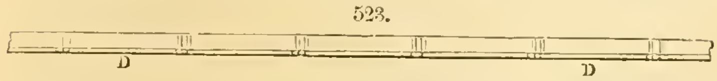

Nash's machine, Figs. 520 and 521, consists in the application of separate or detached moulds of a particular construction to a series of mould-boxes, which are consecutively brought into action; in the employment of heaters, placed in contact with, or contiguous to, the fresh bricks, during the process of their being moulded; and in lieu of sand, which is generally used to prevent the adhesion of the bricks to the moulds, employing elastic absorbent substances, such as cloth saturated with water. In the accompanying engravings, Fig. 520 represents a front elevation, and Fig. 521 an end elevation, of the principal parts of the machine. A vertical shaft *a* is made to revolve in the cylinder or pug-mill *b*, by any adequate force acting upon the beveled wheel *c*. A number of broad steel or iron blades *d d d* are attached to the shaft *a*, their surfaces being set at such an angle as will cause them, during their revolution, to pass nearly in contact with the edges of two other sets of knives *e e e*, fixed on opposite sides of the cylinder, by which means the clay and other materials with which the mill is charged are tempered and amalgamated, and then forced into the hopper *f*, fixed to the lower extremity of the pug-mill. This hopper is divided into two equal chambers by a vertical blade or knife, which

separates the materials into equal portions, which are supplied to the moulds in a compact state. The moulds are lodged in rectangular cavities at equal distances in the periphery of two polygonal drums *g h;* these cavities are marked 1 to 12. To one face or side of the drums are attached two toothed wheels, gearing into each other so as to revolve in opposite directions when motion is communicated to one of them. These wheels, lying at the back of Fig. 520, cannot be seen, but one of them is shown at *i* in Fig. 521. The moulds, after being filled with the plastic material, are pushed out from their recesses by means of pistons at *m m*, easily fitting the recesses, and sliding upon parallel rods fixed to the rims of each drum. To each piston is attached, by a short rod, a cross-head, sliding upon the parallel rods, and having at each end small anti-friction wheels *p p*, which, by the motion given to the machinery, come in contact with a larger wheel *q*, placed eccentrically, which thus raises the pistons, and the moulds which lie upon them are then removed by hand and emptied. During this latter process the emptied mould-receiver will have passed over the centre of the eccentric wheel *q*, and the piston will be descending when the attendant places the emptied mould in its former situation, to be filled again from the hopper as it passes under it. Between each of the rectangular mould-boxes are formed a series of wedge-shaped boxes, termed by the patentees "hollow sectors," into each of which is placed a red-hot iron, the object of which is to expel the superfluous moisture from the newly-formed brick, etc., in order that the manufacture may be conducted in the winter as well as the summer. These irons are heated in the kiln-fires. The axes of the polygonal drums revolve in plumber-blocks, supported upon a strong frame *s;* but as the polygonal drums revolve in close contact, the plumber-blocks are free to slide in grooves in the frame, and the wheels are kept in contact by the action of strong helical springs *t*, which press against the plumber-blocks, the other end of the springs abutting against a regulating screw. In the middle of and underneath the horizontal frame *s* is fixed a knife *u* (supported in its place by a spiral spring), which separates the whole or a portion of the superfluous materials from each mould, as the latter passes over the edge of the former. As some redundancy of material may still be left after the operation of the knife *u*, the exposed surface of the moulds in motion undergoes a similar treatment from two other knives *v v*, fixed to the foundation plate *w* of the machine. A trough or

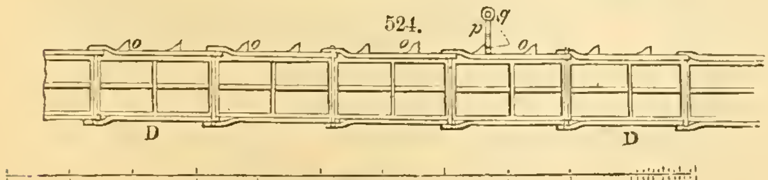
522.



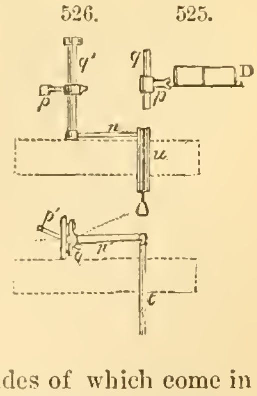
523.



524.



526. 525.

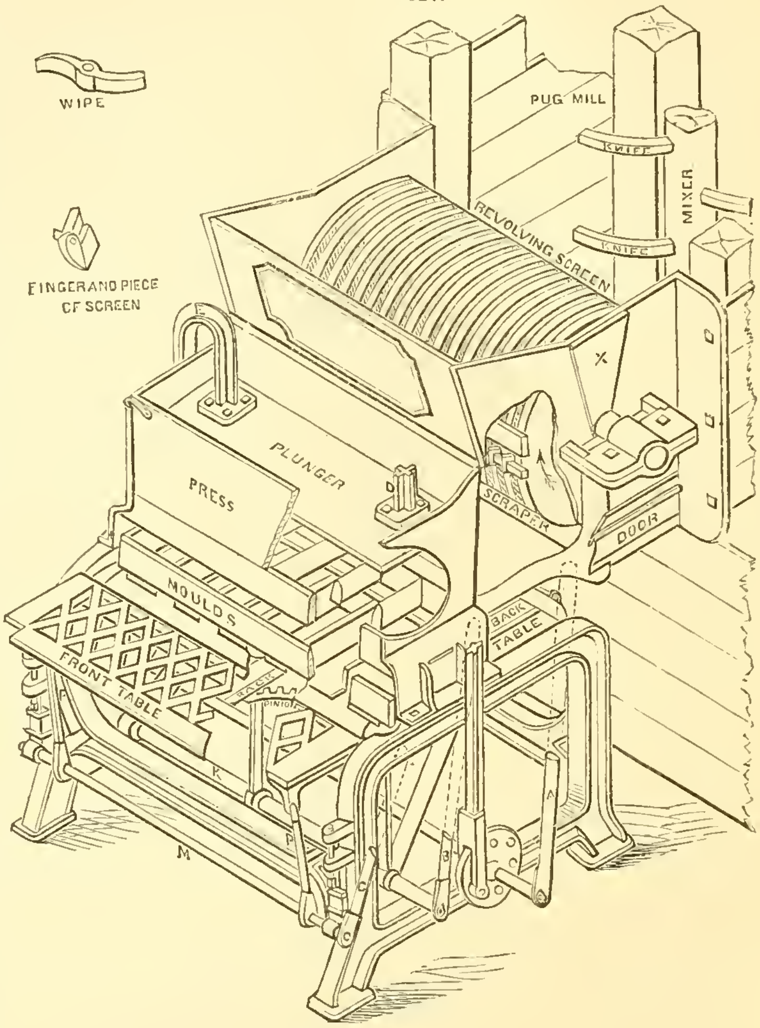


cistern *k k*, containing water, is placed under each of the drums, the lowest sides of which come in contact with a cylinder *y*, covered with strong coarse cloth or other suitable absorbent substance, which as it revolves takes up the water and delivers it to the moulds as before mentioned. These

cylinders are mounted on elastic bearings, and derive their motion from pinions on their axes, actuated by the toothed wheels on the drums. In the centre of the foundation plate there is a cavity, or pit, for the reception of the superfluous clay or other materials, which are removed at pleasure. The pug-mill has a door in it, for the convenience of cleaning it out when requisite; and the whole of the upper part of the machine is supported by three columns *z z z*. The polygonal drums are driven by a set of wheels lying at the back of Fig. 520, and therefore in that figure shown by dotted circles. No. I is a band-wheel, which drives, by a pinion II, the two wheels III and IV, on the axes of the driving gearing, into each other, and turning in opposite directions. Those two wheels must have involute teeth, as their point of contact becomes variable by the movement of the axes of the drums. In case of negligence on the part of the boys, or other attendants of the machine, in not removing the bricks or tiles after the moulds containing them have passed the centre of the eccentric wheel, they fall back into their former position, and pass round to the place of delivery, as before, without any damage whatever being done to the machine.

*Variety* 4. Those in which a series of moulds are linked together to form an endless series, or are placed on an endless belt or track, and are passed beneath the charger, whence they pass to the presser.

527.



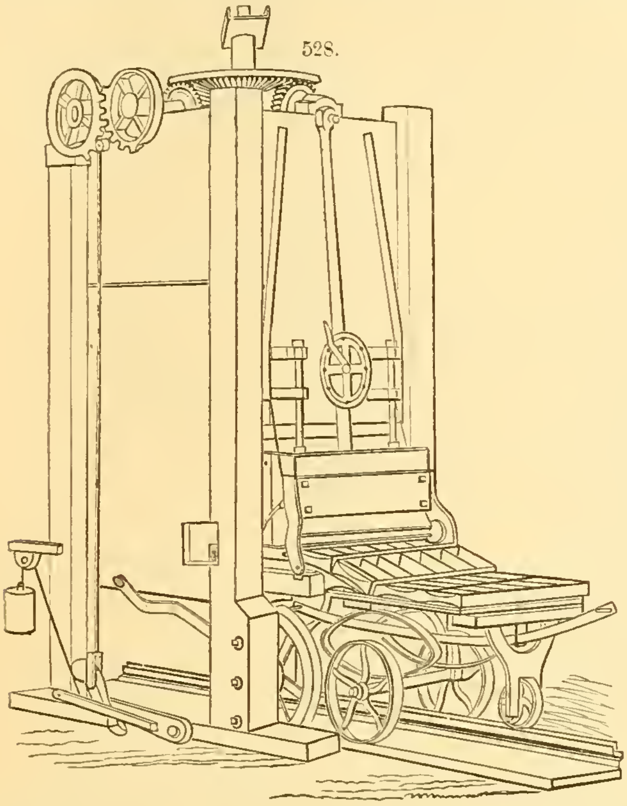

A machine of French invention is illustrated in Fig. 522, in which is employed a cylindrical bottom *A*, the upper part of which is opened in order to introduce the material. An axis *B*, also vertical, to which a rotary motion is imparted by a horse harnessed to the beam *C*, through the medium of the cast-iron socket *A* (see Fig. 522, which is a vertical section through the middle of the machine), rests against two pillows, one adapted to a beam *b*, which unites the opposite sides of the machine, and the other upon an inferior cross-beam. This axis is provided with several flat iron branches *d*, which being fixed perpendicularly to the axis, their faces have an inclination of 45°. On these there are sharp-edged knives, to divide and knead the clay during their rotation; thus the earth is well divided before reaching the inferior part of the barrel. The branches *e f*, stouter than the former, but without knives, are attached at the very extremity of the axis, and receive from it a rotary motion, during which they press against the earth, forcing it out through the orifice *g*. The size of this orifice depends on the quantity needed to fill the moulds; the iron sliding-door *h* regulates this orifice.

M. Carville's machine uses a series of moulds in cast-iron, forming an endless chain *D*, constantly moving; these moulds successively pass beneath the aperture through which the moistened earth is pressed, in order to receive it. Each link forms a rectangular frame, composed of four moulds, which have the precise dimensions of the bricks. Figs. 523, 524 and 525 show a plan and transverse section of this chain. Two wheels, with each four arms *E*, are situated on either side at the extremity of the apparatus. The iron bars *i* support the limbs and impart to them the movement of rotation communicated by the spur-wheel *F;* the arrows indicate the direction in which they are to move, Fig. 522, so that the moulds are carried under the roller *G* after they are filled with earth. This roller is of cast-iron, turning round a horizontal iron axis, set in motion by the beam *C*. Its office is to compress the earth in the moulds as it is received from the barrel. The clay, being thus moulded and pressed, soon meets the blades *l*, made of steel or cast-iron, which shave the two horizontal and parallel faces of the moulds, leveling and polishing the bricks. The latter are then taken out of the moulds by lumps *K*, which are pushed by ingenious mechanism into two corresponding moulds, thrusting the bricks on a movable floor *j'*, which is composed of small plates forming an endless chain which advances a distance equal to the breadth of two bricks. The bricks, being taken off without any handling, are put up to dry.

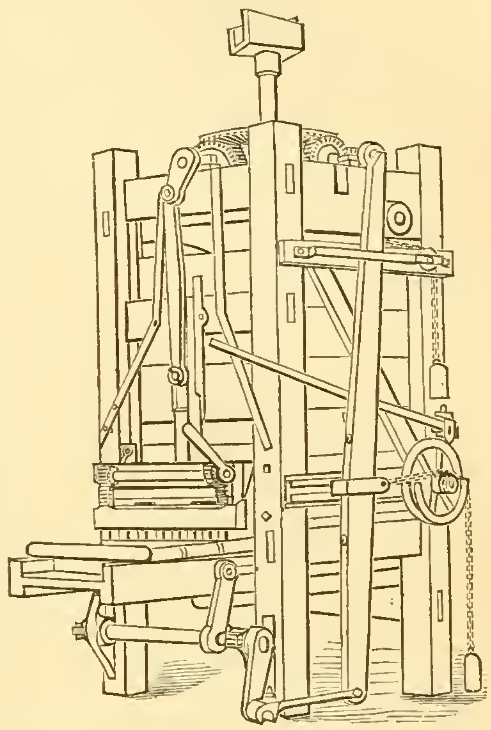
The construction of Blake's machine will be readily understood from Fig. 527. The crude clay is first mixed in the pug-mill, and then is forced through a revolving screen, which removes stones. It is subsequently compressed in the moulds by a plunger, when the table on which the moulds rest is moved outward, and the moulds are removed.

In Hall's machine, Fig. 528, the place for putting the moulds into the machine when sanded is on the opposite side from the pit; the press is on the side lateral with it; the central track is parallel

528.

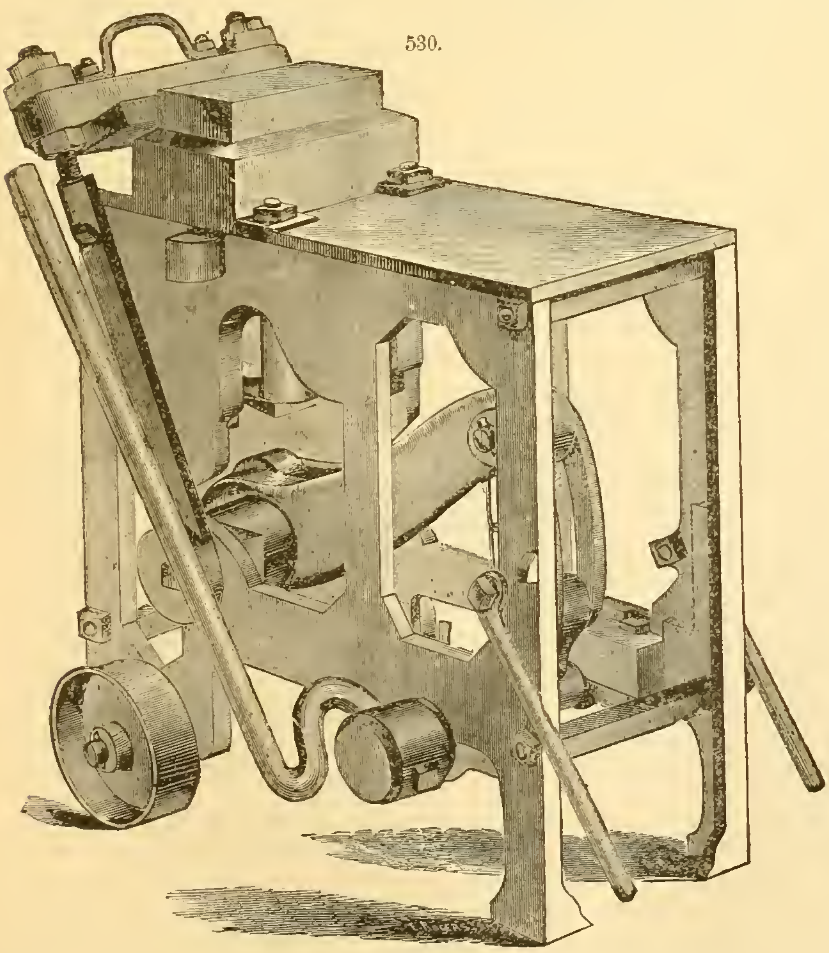


529.



with the pit; the carriage, or support of the moulds, when in the press, rests and is firmly held by the eccentrics. In connection with the carriage is an adjustable table containing friction-rollers.

530.



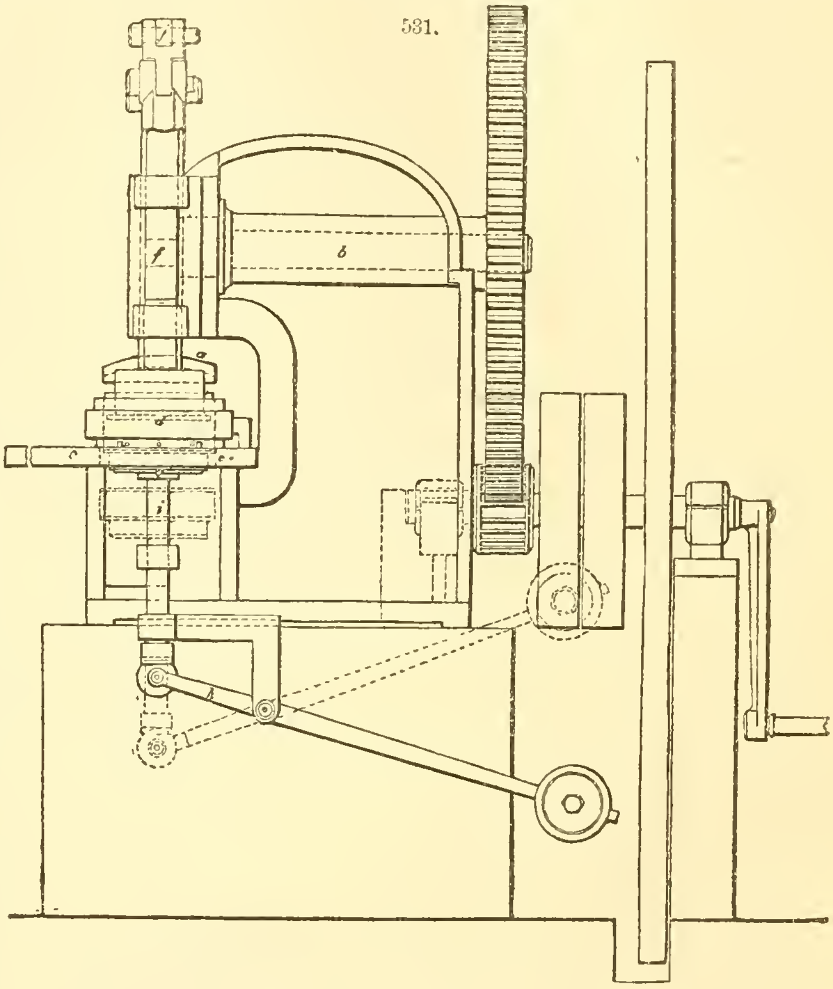
The outside arrangement of the throw-out is composed of several parts: a grooved roller; a slotted arm; a movable or adjustable catch; and a catch in connection with the balance-arm, to which is attached a small weight. If there is any obstruction in the machine by a stone, or a mould being caught, or in any way, then the throw-out remains at rest, thereby insuring perfect safety against any obstruction in using these machines. The weight shown balances the throw-out, and causes it to work perfectly free and easy. The cross-bars are placed in the centre of the mud-box and around the shaft; the knives are bent a little back, in such a manner that they can run close to the bars, operating like a pair of shears. With this improvement, these machines grind the clay in the most thorough manner.

The trucks are put in under on the track far enough to receive the first mould of brick; this mould, as it is thrown from the press, is carried by its own weight on the friction-rollers to the truck; the next follows on and moves the truck along the width of it; and so on until loaded, when it is taken out in the yard and dumped in the usual manner. The next truck is put in position, and the loading goes on as before.

Martin's machine, Fig. 529, is similar in general appearance to that just described. The moulds are delivered by the power of the machine while the press is on, so that the bricks are not drawn up while delivering; wherefore it delivers the bricks very stiff, with well-defined edges and good square corners.

The lever connected with the haul-out is arranged with a movable centre, held by a friction-pulley, so that, should a stone or any hard substance get into the mould, or if by any means the mould should be obstructed, the lever simply moves forward, thus giving time to remove it without stopping the machine, and preventing any part of the machine being broken. Then, by raising the small lever connected with the friction-pulley, the centre moves back, and the machine operates as before.

531.



*Variety* 5. Those in which the clay is moulded by force of a reciprocating piston or pistons.

To this variety belong a large number of small hand-machines similar in general appearance to Carnell's, Fig. 530. This is worked by throwing the movable top-plate over the brick, by means of the handle. Then the lever-bar on the left is depressed, which turns the axle on the right side, and so moves the tumble-joint producing the pressure. The latter is previously set to any desired degree by means of the proper screws and nuts. When the pressure is relieved and the top-plate shifted sideways, the pressed brick is pushed out of the mould by the elevation of its bottom.

In Large's (English) machine, Fig. 531, a plunger *a* is employed, to which a vertical reciprocating motion is imparted by the shaft *b*. The mould is filled, iron plates being inserted both above and below the bricks. The charged mould is brought under the plunger and its contents powerfully compressed. It is then pushed on over an opening in the table, where a second plunger forces the brick out upon a palm held up to it by a counter-weighted rod *h*. As each brick is removed the palm ascends to receive another, and the empty mould is removed.

*Variety* 6. Those in which the moulds are reciprocated beneath a pug-mill.

Brick-machines may also be classified without regard to difference in manner of moulding, as those which use dry or untempered clay directly from the bank; those which use wet clay or mud, necessitating subsequent drying of the bricks; and those which themselves temper the clay. For machines operated by steam or horse power, a production of 30,000 bricks per day is in most cases claimed; for hand-machines the production varies from 2,000 to 4,000 bricks for the same period.

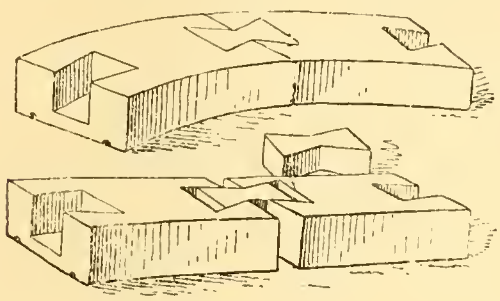
*Forms, etc., of Brick.*—Fig. 532 represents dovetail bricks. In the extremities of each brick are pressed or cut dovetail mortises, which, when the former are placed end to end, come together. Into these portions a connecting piece of suitable form is slipped, which holds the bricks tightly together, mortar at such points being merely auxiliary. Universal-angle bricks are represented in Fig. 533. By combining these bricks angles of various shapes can be made with the walls, the apex of the angle having an ornamental finish. Hollow bricks are made for purposes of warming, ventilating, and removing moisture from walls. It is stated that there is an advantage of 29 per cent. in favor of the hollow bricks over the ordinary bricks, in addition to a considerable diminution in the cost of carriage or transport, and 25 per cent. on the mortar and the labor.

The following are some other forms of brick: "Air-brick" is a grating the size of a brick let into a wall to admit air. "Arch-brick" usually means the hard-burned, partially-vitrified brick from the arches of the brick-clamp in which the fire is made and maintained. A brick made voussoir-shaped is known as a "compass" brick. A "capping" brick is one made for the upper course of a wall. The name "clinker" is given to a brick from an arch of the clamp, owing to the hard, glassy sound emitted when struck. "Stocks" is a name given locally to peculiar varieties of brick, such as gray stocks, red stocks, etc. "Pecking," "place," "sandal," and "semel" brick are local terms applied to imperfectly burned or refuse brick, Burr brick, or those vitrified by excessive heat.

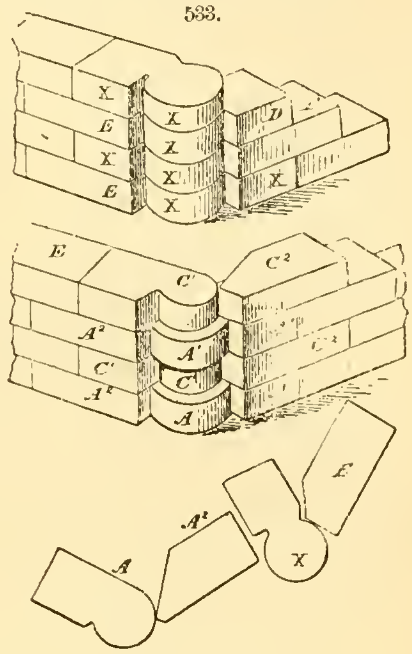
Bricks are glazed or rendered waterproof by a composition which gives them a vitreous surface.

This is performed by treating the surface with a flux which meets the silex of the brick; or it may be applied to the surface in solution, the liquid being afterward expelled by heat. Resinous compounds have also been used to render the surface non-absorbent. Bricks have also been treated with soluble silicate of soda, which has been decomposed, leaving the insoluble silex in the pores of the brick. Pigments added to the glazing compounds give an ornamental appearance.

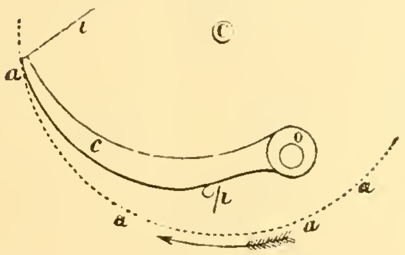
532.



533.



534.

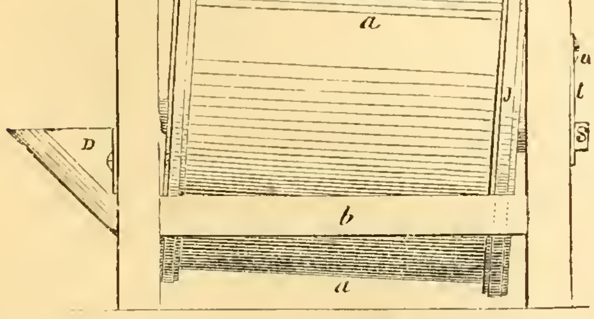


The average specific gravity of brick is 1.841; the weight of a cubic foot, 115 lbs.; the cohesive force of a square inch, 275 lbs. (Tredgold). Brick is crushed by a force of 562 lbs. per square inch (Rennie).

*Other Machines related to Brick-making.*—Special machines are constructed for crushing and pulverizing clay only. The essential feature of the device illustrated in Figs. 534 to 538 consists in the use of a revolving screen working on a stationary axis set at a slight inclination from a horizontal position, and having attached to or suspended from it lugs or crushers, which, by their weight, serve to pulverize the clay; the stock or clay being fed in at one end of the screen, which by its revolving motion carries or drags the stock under the lugs or crushers, thereby breaking and pounding it; the pulverized clay falling through the apertures of the screen, and the waste or hard lumps and stones mixed up with the stock being expelled at the back or lower end of the screen.

Fig. 539 is a machine for making flat tiles, flooring tiles, etc., of any desired breadth or thickness. It may also be adapted to the manufacture of tubes for drain-pipes or other purposes. To the bottom of the pug-mill is fixed a funnel-shaped hopper 23, the materials in which, after being forced

535.



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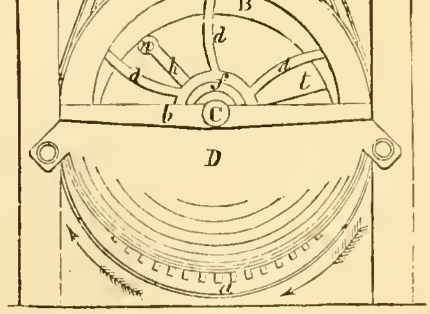


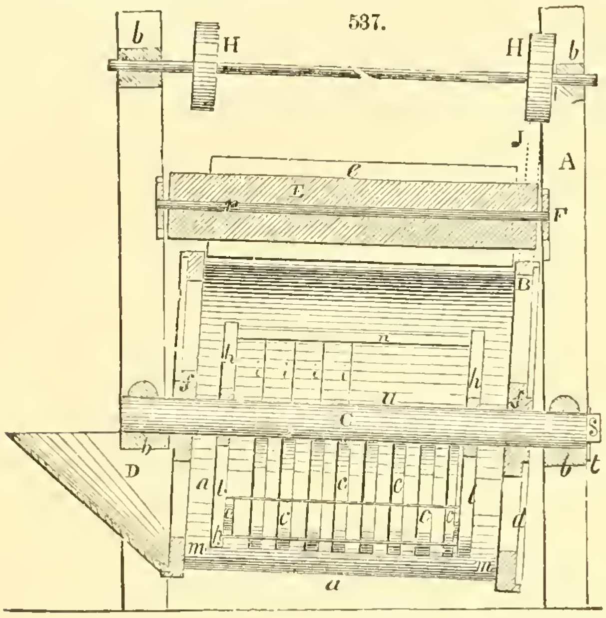
through a mouth 24, formed of the required shape, are received upon boards 25, and, when cut to the proper length, are removed to sheds for drying. In order to equalize the surface of the clay after it has come out of the hopper, a roller 26, turning in bearings on a curved arm, which is fixed to a hinge-joint, gives to the material any pressure that may be required, by loading it accordingly. The dotted lines 27, 27, in the same figure, exhibit another funnel-shaped hopper, for the purpose of making

pipes or tubes, by means of a centre core 28, between which and the cylindrical continuation of the hopper the material is forced by the action of the pug-mill, and produces a tube, which, after the machine has made a certain length of it, is cut off, the tube being turned round to render the inside smooth previously to its being removed.

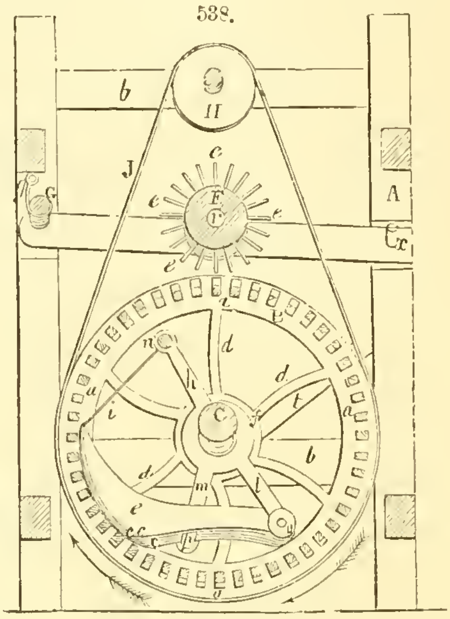
Figs. 540 to 542 represent one of the direct-action steam machines constructed by John Whitehead & Co., of the Albert Works, Preston, England, fitted up with the patent metallic compressed-air die for the manufacture of socketed sanitary or drain pipes.

Fig. 540 gives an elevation of the vertical-acting machine; Fig. 541 shows in plan the patented

537.

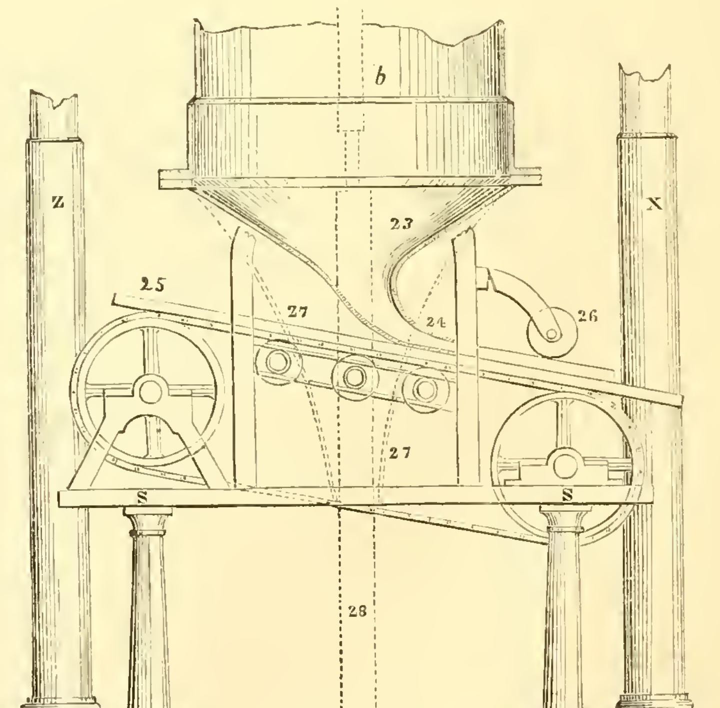


538.



metallic die for making three 6-inch pipes simultaneously, similar in form to the sanitary pipe represented in Fig. 542. The upper cylinder of this machine is the steam cylinder, and is constructed in the same manner as those in ordinary use in steam engines. It is, of course, made of various dimensions in accordance with the size of the clay cylinder below it, and of the pipes intended to be made in these machines. The piston-rods have a ram attached to them, which, upon steam being admitted to the cylinder, descends and forces the clay in the shape of pipes out of the clay cylinder, which is immediately below it. It will be seen from Fig. 540 that the admission of steam through the steam-chest is under easy control of the attendant by means of a handle close to him. The clay cylinder is fitted with an expanding mouthpiece at the bottom, by means of which pipes of large diameters are obtained. The dies for both small and large pipes are attached to the before-mentioned mouthpiece; and on referring to Fig. 540 a balanced receiving-table will be seen immediately under the die. As the pipe comes from the machine this table continues to fall; and, as soon as the pipe is removed, it rises with its face against the die in readiness for the ram to descend and push out another pipe. During the time the socket of the pipe is being formed, the table is held fast by a wedge actuated by a lever, the handle of which is shown in Fig. 540, in the hand of the man in charge. On the attendant releasing the table, and on steam being admitted above the piston, the ram continues its downward course, and the pipe or pipes, as the case may be, issues through the die.

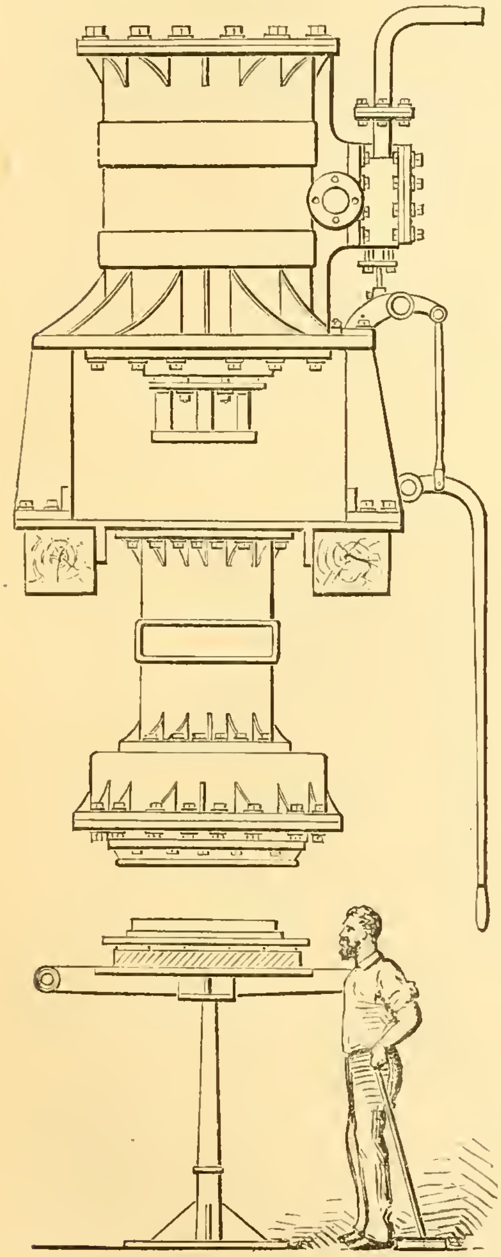
539.



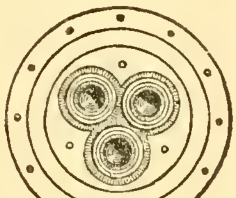
A simple machine for making drain-pipe is represented in Fig. 543. The material is mixed in the upper cylinder, and pressed into the mould below, the latter being held up to its place by the weights shown, and hence easily removable for the extraction of the moulded pipe, which is of the form shown on the right.

*Slag Bricks.*—Figs. 544 and 545 represent an improved press for the manufacture of bricks from blast-furnace slag. The pressure is given by two cast-steel cams, which are fixed upon a forged steel shaft $7\frac{1}{2}$ inches in diameter. This shaft, resting on bearings between two strong A-frames, is put in motion by very powerful double-geared spur-wheels, the first motion shaft having a heavy fly-wheel upon it to steady and equalize the pull upon the strap. The pressure-cams, marked *B* on the diagram, act against rollers fixed upon two steel cylinders or rams *X*. These rams transmit the pressure to the moulds in the table marked *C*. The table is circular, and contains 6 pairs of moulds, so that 4 bricks are pressed at one time, the table remaining stationary during the operation. At the same time the bricks are being pressed, 2 other pairs of moulds are being filled up with material—

540.

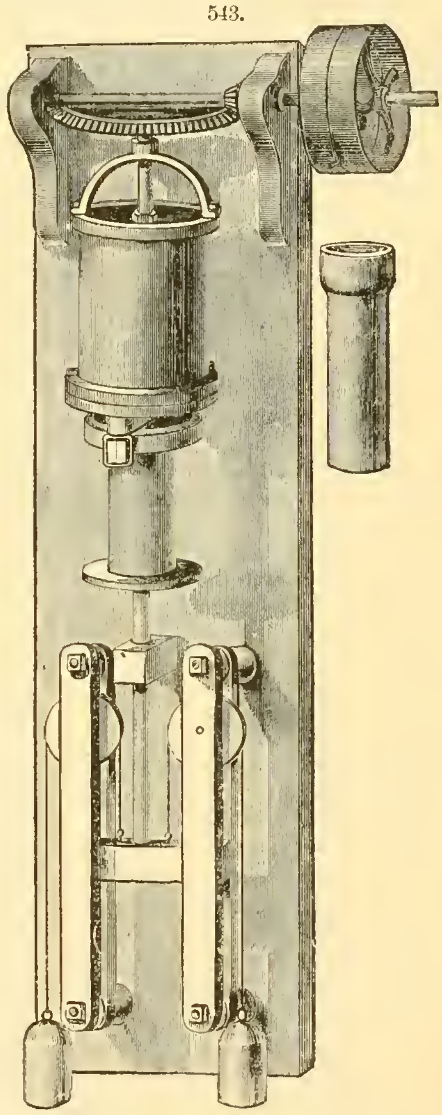


541.



542.

543.

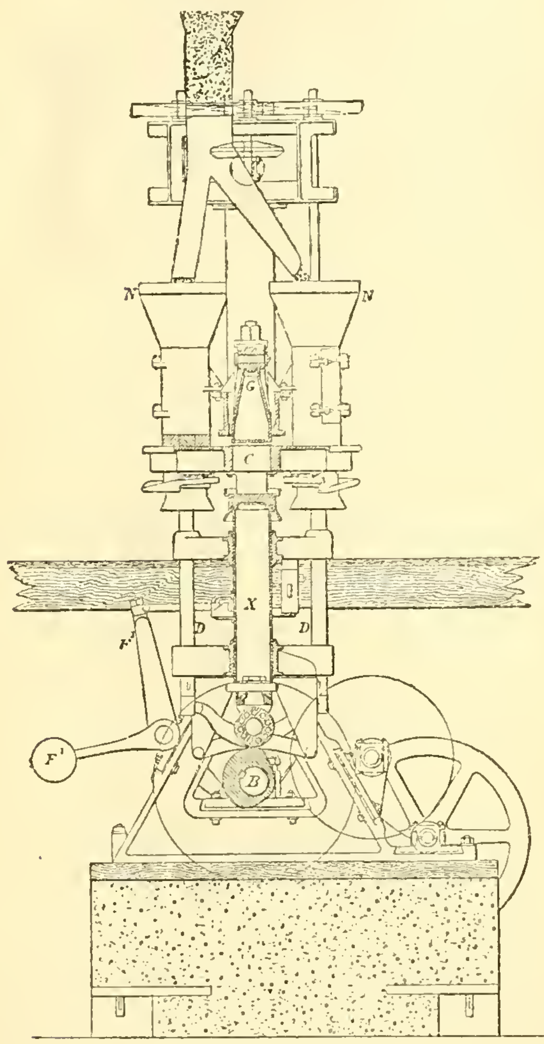


while the other 2 pairs are delivering up the 4 bricks pressed at the previous revolution of the cam shaft. The bricks are pushed out of the mould by smaller pistons marked *D*, acted upon by the separate cams marked *E*. The moulds are lined with changeable steel plates three-sixteenths of an inch thick, and the sand and lime is fed into them by two pug-mills *N*. These pug-mills are fitted with 6 knives each, so as the more thoroughly to mix and chop the spongy slag along with the lime. The table is shifted round by a kind of ratchet motion, also worked by a cam on the outside of the frame-work marked *F*, and acting upon the weigh-bar and levers $F^1$. Immediately above the pressure-cylinders are two pressure-stops *G*, which are held down by the heavy-weighted levers *H*. These levers *H*, therefore, receive the whole pressure put upon the bricks; and in case there should be too much sand getting into the moulds, they simply lift up and relieve the strain. The weights *I* can be weighed at option, and thus form an exact gauge of the pressure upon the bricks. The moulds are generally filled so as just to lift the levers in ordinary work. The filling is easily regulated by the set of the knives on the pug-shafts, which press the material into the moulds *C*, and one side of the pug-mill cylinder is made to open so that the knives are accessible at any moment. The pug-mills are filled by means of the measuring and mixing apparatus placed on the floor immediately above the brick press. The mixing and measuring apparatus is very simple and efficient, and works without any trouble. The slag-sand is tipped into a hopper by large barrows, which are lifted up by a hoist. At the bottom of this hopper there is a revolving cylinder with ribs cast upon it, which, revolving under the hopper, carries a certain thickness of sand, the thickness having been previously regulated

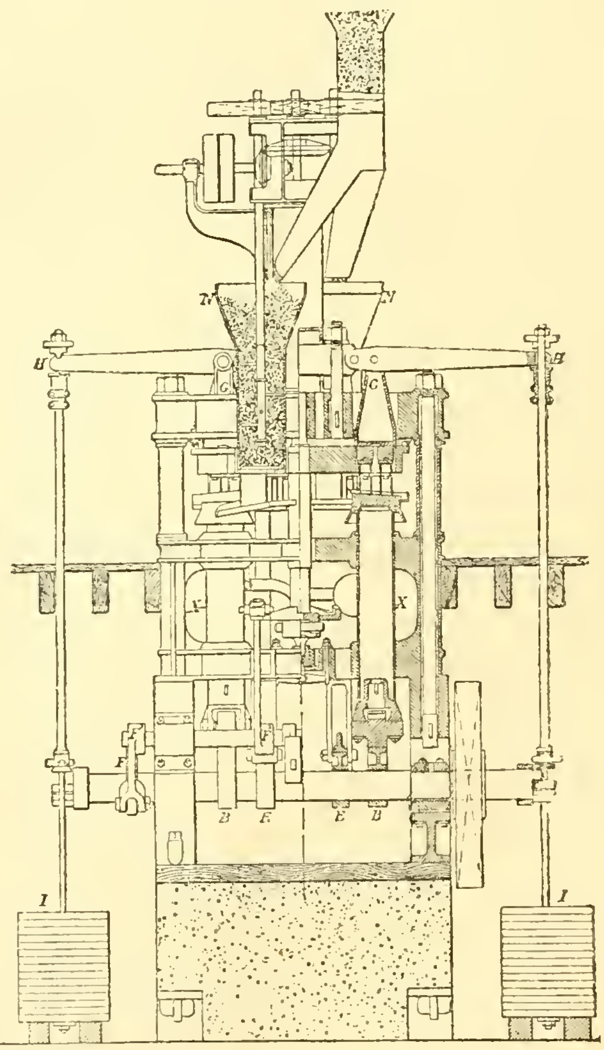
to the requirements of the press. The slag then falls upon a sieve, which separates any large pieces of slag in a solid state, and at the same time allows the falling sand through the sieve to fall like a shower. The lime is fed into a separate hopper, and is regulated very much like the feed of corn into millstones. The lime then passes down a shoot, which forms part of the slag-sand sieve, where it meets the shower of sand—falling together with it—thus getting thoroughly mixed. As before stated, this lime is selenitic lime, and is prepared upon the works. The bricks, when taken from the brick-press, are placed upon spring barrows, holding 50 each. They are then taken and stacked in sheds, where they are allowed to remain about 5 or 6 days, after which they are simply stacked outside in the weather to harden. The percentage of loss is very little, not amounting to 2 or 3 per cent. In fact, when once the bricks are upon the barrows there is little or no waste.

Each machine is capable of turning out about 10,000 bricks per day. The following are a few of the advantages claimed for these concrete slags and bricks, viz.: Being pressed, they are perfectly uniform in size and thickness; they are much cheaper than ordinary red bricks, compared in weight with which they will weigh one ton per thousand less; and there is this further advantage, that there are no wasters or halves. For inside work there is a great saving both in bricklaying and mortar, more especially when plastering, the walls being of uniform thickness; and the bricklayers like

544.



545.



them, because they can do more work with less labor, the bricklayer's laborer finding he has a ton per thousand less to carry, as well as considerably less mortar. Another remarkable property of the slag brick is that the joiners can drive nails directly into them without splitting, and thus, for skirting and door-work, they are saved much trouble in plugging the walls. And finally, the longer the bricks are kept the harder they get.

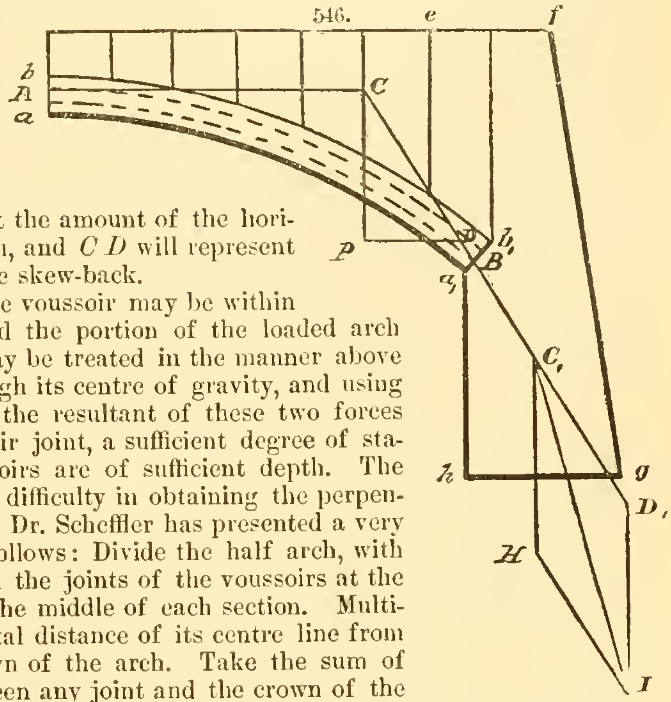
BRIDGES. Bridges are constructed of various materials; usually of wood, stone, brick, iron, or steel. These are arranged in a variety of forms, as in arch, girder, truss, and suspension bridges. In their various positions, the members of a bridge are liable to strains of compression, extension, and detrusion. Most of these strains may be determined theoretically by the composition and resolution of forces. The ability of the material to sustain such strains has been ascertained by numerous experiments. See Strength of Materials.

*Arched Bridges of Stone or Brick.*—The forms of arches are varied; the semicircular, segmental, elliptical, parabolic, pointed, and three or more centered arches, are all used, but the most common in this country is the segmental. See Arches.

The following technical terms are explained by reference to Fig. 546. Each individual arch-stone is termed a "voussoir;" the one occupying the highest point of the arch is called the "keystone." The exterior and interior lines of the arch are termed respectively "extrados" and "intrados;" the

highest portion of the intrados is called the "crown of the arch," as lines $b\ b$ and $a\ a$. The surface upon which the first voussoir rests is called the "skew-back," of which $a\ b$ is a line. The horizontal line at $a$ is termed the "springing-line" of the arch. The strains upon an arch arise from the gravity of the structure and the load imposed upon it. Although they act vertically, yet the resulting forces act in different directions, and with diverse intensities. These have been the subject of much careful study and numerous experiments connected with the construction of such bridges. Considerable light may be thrown upon the strains and resulting forces in the arch by the following graphic representation: Let $a\ b\ a_{,}\ b_{,}$ (Fig. 546) represent one-half of an arch loaded. Through the centre of gravity of the loaded half arch draw the perpendicular $C\ P$. Then from $A$, one-third of the depth of the crown from the top, draw the horizontal line $A\ C$.* From $C$ draw the line $C\ B$, intersecting the spring or skew-back of the arch $a_{,}\ b_{,}$ at $B$, one-third of its depth from the face. Measure from $C$ by scale a distance $C\ P$, representing the weight of the half arch loaded; then from $P$ draw a line parallel with $A\ C$, meeting the line $C\ B$ in $D$; then will $P\ D$ represent the amount of the horizontal force acting at the crown of the arch, and $C\ D$ will represent the line of thrust and the force acting at the skew-back.

546.




That the centre of pressure between the voussoir may be within safe limits, any joint may be selected, and the portion of the loaded arch lying between such joint and the crown may be treated in the manner above described by drawing a perpendicular through its centre of gravity, and using the pressure $P\ D$ as a constant. Then, if the resultant of these two forces falls within the middle third of the voussoir joint, a sufficient degree of stability will be assured, provided the voussoirs are of sufficient depth. The objection to this method of solution is the difficulty in obtaining the perpendicular line through the centre of gravity. Dr. Scheffler has presented a very simple method for obtaining this line, as follows: Divide the half arch, with its load, into sections by vertical lines from the joints of the voussoirs at the extrados. Draw a line vertically through the middle of each section. Multiply the area of each section by the horizontal distance of its centre line from the vertical line passing through the crown of the arch. Take the sum of the products of all the sections lying between any joint and the crown of the arch, and divide this sum by the sum of the areas of said sections; this will give the horizontal distance of the centre of gravity of that portion of the arch between its crown and the joint taken, within a sufficient degree of accuracy for general practice.

The depth of voussoirs cannot be computed by simply providing against crushing, but must be made deep enough to permit of considerable latitude in the line of pressures. To meet these requirements, Prof. Rankine gives the following formula: Depth of keystone in single arch in feet $= \sqrt{.12 \times \text{radius at crown}}$, and for a series of arches $\sqrt{.17 \times \text{radius at crown}}$.

The abutment, to be capable of supporting the arch, must have the resultant line of pressure derived from the arch-thrust and its own gravity fall within its base a safe distance. This is determined as follows: Having found the line of thrust of the loaded half arch at the skew-back, as heretofore described, produce the line $C\ D$ thus found, intersecting the vertical drawn through the centre of gravity of the abutment at $C$. Lay off from the point of intersection $C_{,}\ D_{,}$ equal to the force $C\ D$ acting on the skew-back. Also lay off on the vertical the distance $C_{,}\ H$ equal to the weight of the abutment. Completing the parallelogram, then will $C_{,}\ I$ represent the line and amount of pressure intersecting the base of the abutment about one-third of its width from the exterior, a limit of stability safe in practice.

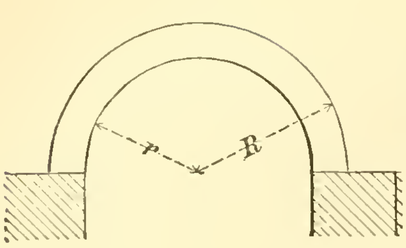
The point of intersection at any bed between courses of masonry may be ascertained by regarding such bed as the base of the abutment, and proceeding as above. In the abutments of flat arches, although the line of pressure may fall amply within the base, yet the thrust may be sufficient to cause rupture by sliding upon some one of its courses of masonry. Stability is assured when the angle with the horizontal, which the resultant of the thrust of the arch and the weight of that portion of the abutment above the joint in question makes, exceeds the angle of friction of the material used. Should there be danger apprehended, the bed-joints of the courses may be inclined from the horizontal, as a further security.

In the construction of arch bridges, it is necessary to erect a framework which shall sustain the lower voussoirs until the keystone is set and the arch becomes self-sustaining. See engraving of Waterloo Bridge.

Arched bridges are also built of wood, cast and wrought iron, and steel. As most of these arches are built in conjunction with trusses, they will be further referred to under the head of "Trussed Arch Bridges." Perhaps there is no branch of bridge-building where theory has been so inadequate to furnish practical rules as in the proportions of an arch. The proper depth of the crown or keystone is still left to empirical rules. For smaller culverts of 15 to 30 feet span, the usual construction is to make the arch from 1 foot 6 inches to 2 feet deep. Arches in stone are seldom turned less than 1 foot deep, whatever may be the span; brick arches for less than 10 feet span are generally 8 inches, and this depth is required by building acts.

* The theoretical point where the centre of pressure would occur in a perfectly rigid and evenly balanced arch is at one-half the depth of the crown; one-third is here taken as the proper practical variation.

547.



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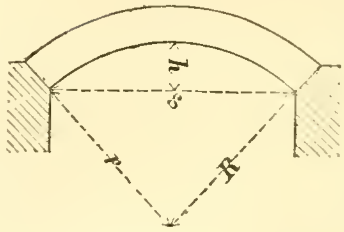

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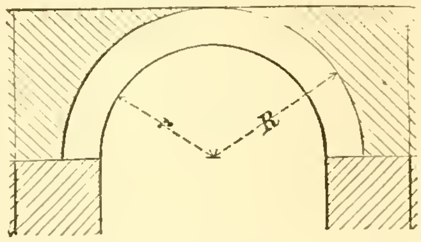


Perronet has given as a rule for the depth at the crown the formula $d = .07\ r + 1$ foot, in which formula $r$ is the greatest radius of curvature of the intrados. This formula is applicable to arches of less than 50 feet radius; but beyond this it gives greater dimensions than in ordinary practice. In order to facilitate investigations on the stability of arches of the more usual forms, M. Petit calculated a series of tables, of which we give the abstract for circular arches, as the class occurring most frequently in practice.

To find the thickness of abutment necessary to support the thrust of the arch, multiply the coefficient found in the table for the particular case by 3.8, and the square root of the product multiplied by the radius, $r$, of the intrados, will give the extreme thickness of the abutment.

COEFFICIENT OF HORIZONTAL THRUST AT THE CROWN.

| RATIO OF THE RADII, $\frac{R}{r}$ | Fig. 547. | Fig. 549. | Fig. 548. | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | s = 4 h, $\frac{r}{h} = 2.5$ | s = 5 h, $\frac{r}{h} = 3.265$ | s = 6 h, $\frac{r}{h} = 5$ | s = 6 h, $\frac{r}{h} = 8.5$ | s = 10 h, $\frac{r}{h} = 13$ | s = 16 h, $\frac{r}{h} = 32.5$ |
| 1.50 | 0.191 | 0.217 | ..... | ..... | ..... | ..... | ..... | ..... |
| 1.45 | 0.168 | 0.192 | ..... | ..... | ..... | ..... | ..... | ..... |
| 1.40 | 0.162 | 0.169 | 0.154 | 0.147 | 0.147 | 0.147 | 0.145 | ..... |
| 1.35 | 0.153 | 0.147 | 0.148 | 0.130 | 0.126 | 0.126 | 0.124 | ..... |
| 1.30 | 0.143 | 0.143 | 0.137 | 0.123 | 0.106 | 0.106 | 0.104 | ..... |
| 1.25 | 0.128 | 0.139 | 0.126 | 0.114 | 0.100 | 0.086 | 0.084 | 0.072 |
| 1.20 | 0.111 | 0.131 | 0.110 | 0.102 | 0.091 | 0.070 | 0.066 | 0.056 |
| 1.15 | 0.092 | 0.119 | 0.091 | 0.086 | 0.079 | 0.063 | 0.049 | 0.041 |
| 1.10 | 0.068 | 0.103 | 0.067 | 0.065 | 0.062 | 0.052 | 0.042 | 0.027 |
| 1.05 | 0.038 | 0.082 | 0.038 | 0.038 | 0.037 | 0.034 | 0.029 | 0.019 |

*Example.*—What is the horizontal thrust, and what the thickness of abutment, necessary to support an arch of 10 feet span and 2 feet rise?

$$\frac{s}{h} = \frac{10}{2}, \text{ therefore } s = 5h. \quad \frac{r}{h} = \frac{r}{2} = 3.625. \quad r = 3.625 \times 2 = 7.25 \text{ feet.}$$

By Perronet's formula, $d = 0.07 \times 7.25 + 1 = 1.50$. $R = 7.25 + 1.50 = 8.75$. $\frac{R}{r} = \frac{8.75}{7.25} = 1.20$.

By the table against 1.20, under the column $s = 5h$, we find 0.102 as the coefficient of thrust; 150 lbs. being taken as the average weight of a cubic foot of masonry, the absolute thrust per square foot of surface is $0.102 \times 150 \times 7.25^2 = 804$ lbs. $\sqrt{0.102 \times 3.8 \times 7.25} = 4.50$ feet, thickness of abutment. The formula gives the thickness of abutment, supposing the height infinite; for low abutments, the thickness may be reduced, for common spans, about 10 per cent.

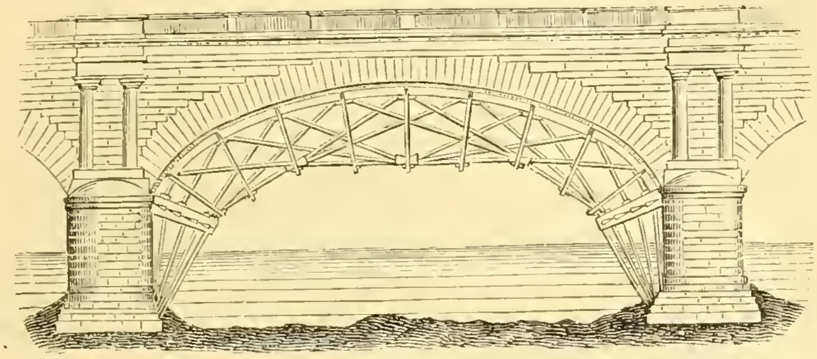
In the loading of a semicircular arch, especially, the tendency of a weight applied at the crown is to raise the haunches. This is to be counteracted by a backing of masonry at these points, called the spandrel backing. When the arch is to be covered with earth, care should be taken in loading the arch evenly at both sides. The same remark applies to the setting of the arch-stones on the wooden centres while in process of construction.

The dimensions of some of the most noted arch bridges in the United States and Europe are:

| LOCATION. | Material. | Form of Arch. | Span. | Rise. | Depth at Crown. | Depth at Spring. |
|---|---|---|---|---|---|---|
| | | | ft. in. | ft. in. | ft. in. | ft. in. |
| Manchester and Birmingham Railroad | Brick.... | Semicircular.. | 18 | 9 | 1 6 | Uniform. |
| " " " " | " .... | " | 63 | 31 6 | 3 | " |
| London and Brighton " | " .... | " | 30 | 15 | 1 6 | 2 3 |
| " Blackwall " | " .... | Segmental... | 87 | 16 | 4 1½ | Uniform. |
| Great Western " | " .... | Elliptical..... | 128 | 24 3 | 5 | 7 1½ |
| Orleans and Tours " | Stone.... | Semicircular.. | 27 7 | | 2 7½ | Uniform. |
| Stirling Bridge | " .... | Segmental.... | 60 | 13 6½ | 3 6 | 4 6 |
| Carlisle " | " .... | Elliptical..... | 65 | 21 | 3 9 | 7 4 |
| Staines " | " .... | Segmental ... | 74 | 9 3 | 2 4 | 5 6 |
| Hutcheson " | " .... | " ... | 79 | 13 6 | 3 6 | 4 6 |
| Jena " | " .... | " ... | 71 9 | 10 9 | 5 | |
| Cabin John, Washington Aqueduct | " .... | Elliptical..... | 220 | 57 25 | 4 16 | |
| Licking Aqueduct, Chesapeake and Ohio Canal | " .... | " ..... | 90 | 15 | 2 83 | |
| Monocacy " " " " | " .... | " .... | 54 | 9 | 2 5 | |
| Falls Bridge, Philadelphia and Reading Railroad | " .... | Segmental ... | 78 | 25 | 3 0 | |
| Chestnut Street, Philadelphia | Brick in cement. | " ... | 60 | 18 | 2 5 | |
| James River Aqueduct, Virginia | Stone.... | " ... | 50 | 7 | 2 66 | |
| Tonoloway Culvert, Chesapeake and Ohio Canal | Rubble in cement. | " ... | 40 | 15 | 2 | |
| High Bridge, New York City | Stone ... | Circular... .. | 80 | 40 | 2 5 | 2 5 |

Waterloo bridge, London, by Rennie, is considered a masterpiece. It was commenced in 1810; it is a level bridge, having 9 arches, each 120 feet span and 35 feet rise, and it is 42 feet 4 inches wide between the parapets.

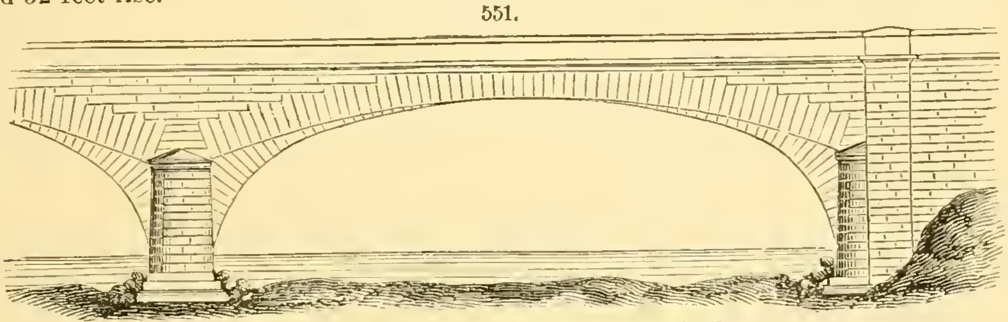
550.



Details of one of the Arches and Centreing of Waterloo Bridge.

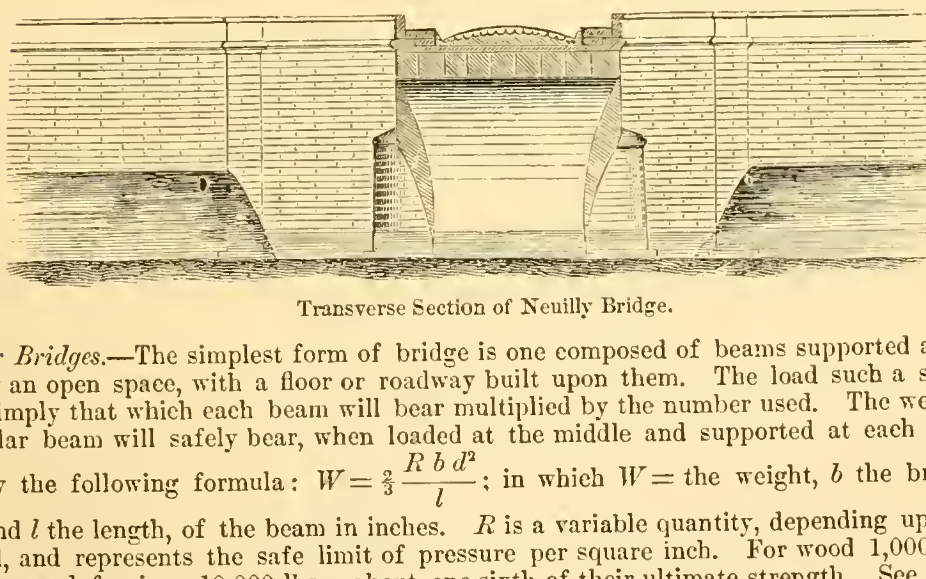
The bridge across the Seine, at Neuilly, built between the years 1768 and 1780, by Perronet, is a very celebrated structure; it is also a level bridge, consisting of 5 elliptic arches, each of 128 feet span and 32 feet rise.

551.



Elevation of one of the Arches of Neuilly Bridge.

552.



Transverse Section of Neuilly Bridge.

*Girder Bridges.*—The simplest form of bridge is one composed of beams supported at their ends, spanning an open space, with a floor or roadway built upon them. The load such a structure will bear is simply that which each beam will bear multiplied by the number used. The weight a single rectangular beam will safely bear, when loaded at the middle and supported at each end, may be found by the following formula: $W = \frac{2}{3}\frac{R\,b\,d^2}{l}$; in which $W =$ the weight, $b$ the breadth, $d$ the depth, and $l$ the length, of the beam in inches. $R$ is a variable quantity, depending upon the material used, and represents the safe limit of pressure per square inch. For wood 1,000 lbs. is usually taken, and for iron 10,000 lbs.—about one-sixth of their ultimate strength. See STRENGTH OF MATERIALS.

Wooden beams or "girders" are generally rectangular. Beams of iron or steel are mostly built of the I or T form, and frequently with riveted flanges. The capability for sustaining loads depends materially upon the method of support and the application of the load. The relative weights the same beam will sustain under the various conditions are given below:

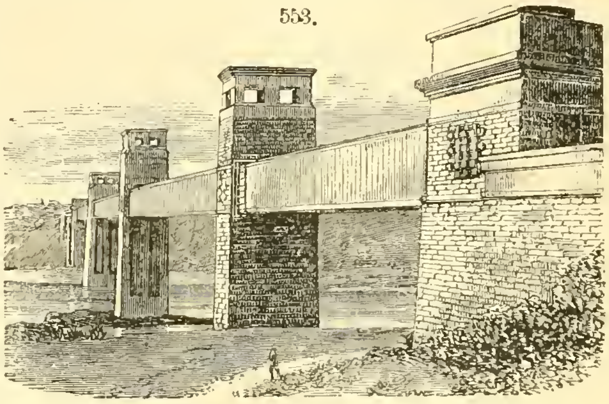
| | |
|---|---|
| Beam supported at one end, loaded at the other end | 1 |
| " " " load uniformly distributed | 2 |
| " " at both ends, loaded at middle | 4 |
| " " " load uniformly distributed | 8 |
| Beam firmly fixed at both ends, load uniformly distributed | 16 |

The tubular bridge is properly classed as a girder bridge, and is the crowning point in the use of the girder. Each span, in effect, is simply an immense girder.

The Conway Tubular Bridge was built by Robert Stephenson, and has one span of 400 feet, consisting of two tubes placed side by side. A peculiar feature of its construction was the fact that each tube was built entire, then floated to and raised into position by hydraulic power. The Britannia Bridge,

Fig. 553, across Menai Straits, is of similar character. It was also built by Stephenson, has two spans of 230 feet each, two of 459 feet each, and is 103 feet above the water. The Victoria Bridge, by the same, across the St. Lawrence at Montreal, is also a tubular bridge, and is the largest in existence, being 6,538 feet long. It has 24 spans of 242 feet each, and a central span of 330 feet. Each tube spans two openings, being fixed at the centre, and free to expand or contract at either end.

553.

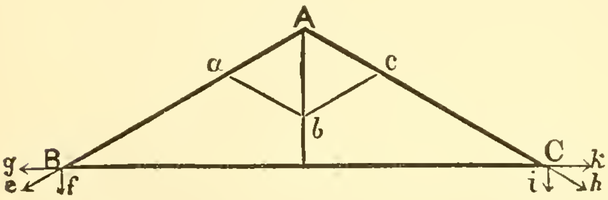


*Pile Bridges* consist of timber "stringers," or beams, supported at short intervals on piles driven in the ground in rows at right angles with the stringers. Upon these rows of piles caps are laid, which support the stringers on which the floor or roadway is laid.

*Truss Bridges.*—Simple beams or girders are only applicable to small spans, 15 to 20 feet being the usual limit. For greater spans framed structures are necessary, forming what are called "truss bridges." The general principles of the "truss" may be shown briefly as follows:

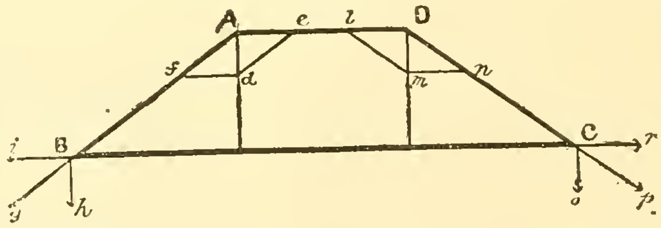
The problem in all trusses is to transmit vertical forces, acting at unsupported points, to the points of support, or piers. We will first consider the case where the loads are equal and placed at equal distances from the piers. Let $A\,B\,C$, Fig. 554, be a simple truss loaded at $A$, and let the line $A\,b$ represent this load. Then, by the resolution of forces, the strains upon the members $A\,B$ and $A\,C$ are represented by the lines $A\,a$ and $A\,c$. These are again resolved at $B$ and $C$ into $B\,g$ and $B\,f$ at $B$, and $C\,i$ and $C\,k$ at $C$. The two vertical forces $B\,f$ and $C\,i$ are neutralized by the piers; the two opposite horizontal forces, $B\,g$ and $C\,k$, neutralize each other, producing tension on the tie $B\,C$. We see in this that the vertical forces acting at the piers are equal to the whole load; and that, although horizontal forces are developed, yet they do not bear any part of the load, but are simply evolved in transmitting the weight to the piers, which eventually bear it all.

554.



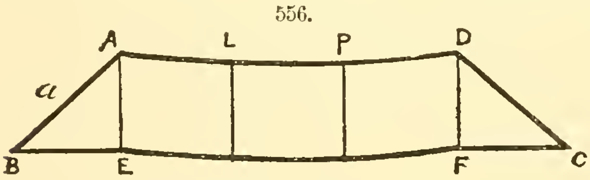

This form of bridge-building is applicable to spans of from 15 to 30 feet.

555.




For greater spans, the additional member $A\,D$, Fig. 555, is introduced, the tie rods at $A$ and $D$ dividing the span into three parts. $A\,d$ and $D\,m$, representing the weight acting at $A$ and $D$, are resolved into the equal vertical forces $B\,h$ and $C\,o$ acting at the piers, the opposing horizontal strains $A\,e$ and $D\,l$ compressing the beam $A\,D$, and the opposing forces $B\,i$ and $C\,r$ producing tension on the tie $B\,C$. If the truss be lengthened, as in Fig. 556, and loaded at the additional points $L$ and $P$, though these weights would be transmitted as before to the piers through $A\,B$ and $D\,C$, yet they may be sufficient to deflect the beams $A\,D$ and $E\,F$, as shown in Fig. 556. To obviate this, the additional braces $L\,E$ and $P\,F$, Fig. 557, are introduced, resting upon the supported points $E$ and $F$. Through these the weights acting at $L$ and $P$ are transmitted to $E$ and $F$, thence by the rods $A\,E$ and $D\,F$ to $A$ and $D$, and thence by the braces $A\,B$ and $D\,C$ to the abutments. The truss may be further lengthened, as in Fig. 558, but the action of all the parts may be shown to be precisely the same as in the more simple cases. The vertical strains are transmitted to the abutments, while the horizontal strains neutralize each other by compression of the upper and tension upon the lower chord. The same result may be obtained by using vertical posts and inclined ties, or by the inversion of the truss, as shown in Fig. 559. The various parts should be in proportion as the strains they are to bear, as follows: Let $w$ represent the weight upon one panel, $n$ the number of

556.

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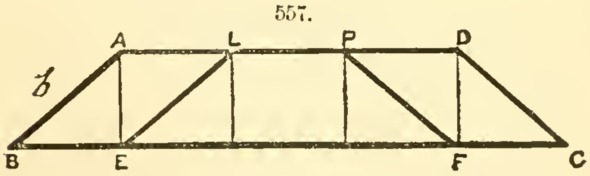


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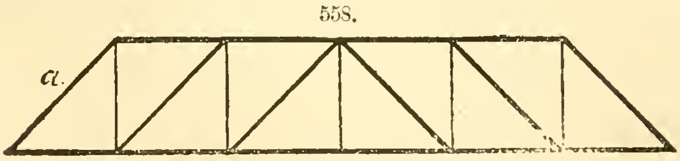


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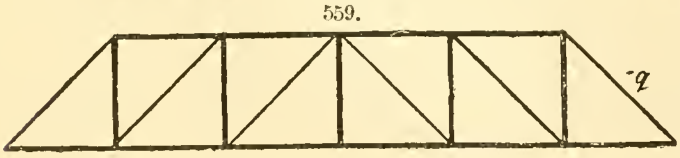
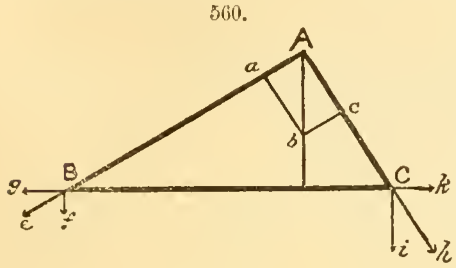


panels, $p$ the length of a panel, $h$ the height, and $b = \sqrt{p^2 + h^2}$, the length of a brace. The centre braces should each be sufficient to transmit the weight upon one panel, the strain being $\frac{w\,b}{2\,h}$. The end braces should each be sufficient to bear one-half the whole weight, their strain being $\frac{n\,w\,b}{2\,h}$. The intermediate braces should be in due proportion from the centre to the ends. The vertical rods should each be as its adjacent brace toward the centre multiplied by the factor $\frac{h}{b}$. The strains upon the upper and lower chords are equal, the former being a strain of compression and the latter of tension. At the ends this equals the strain upon the end braces multiplied by the factor $\frac{p}{b} = \frac{n\,w\,p}{2\,h}$. At the centre the strain is $\frac{n\,w\,l}{8\,h}$. These formulæ are applicable only to a truss uniformly loaded. If the truss be unequally loaded, the conditions are somewhat modified, as seen by Fig. 560. The horizontal strains $B\,g$ and $C\,k$ are equal and opposite as before; but the vertical strains $B\,f$ and $C\,i$ are found to be in inverse proportion to the horizontal distance of the load from each pier. If the truss, Fig. 555, be loaded only at $D$, the horizontal force $D\,i$ not being neutralized by the equal and opposite force $A\,c$, a distortion takes place, as shown in Fig. 561—the weight depressing the point $D$ and raising the points $A$ and $E$. If a brace be introduced from $E$ to $D$, Fig. 562, it prevents this distortion; such a brace is called a counter-brace. A similar brace from $A$ to $F$ prevents flexure when the load is at $A$.

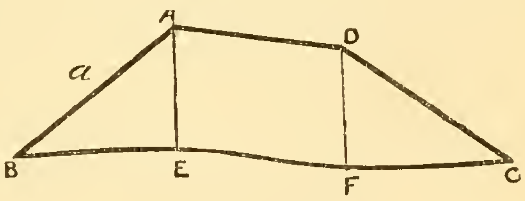
560.



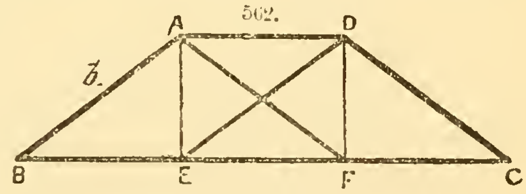

As may be seen by Fig. 561, the load at $D$ develops a force at $A$ acting upward.

The consideration of this force is of the greatest practical importance, and the existence of a force acting upward appears to have been overlooked by many practical builders, as in some very important structures no means have been used to guard against its effects.

561.



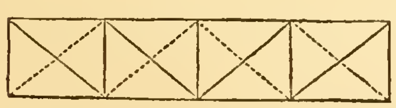

562.




The consequence is that, in a straight as well as in an arched truss, a weight at one side produces a tendency to rise at the other side.

The effect of this upward force is to compress the diagonals in the direction of the dotted lines, Fig. 563, and extend them in the direction of the braces; but as the braces, from the manner in which they are usually connected with the frame, are not capable of opposing any force of extension, it follows that the only resistance is that which is due to the weight and inertia of a part of the structure. When the load is uniform this is sufficient, because the weight on one side is balanced by an equal weight upon the other, and every part is in equilibrium. But when the bridge is subjected to the action of a heavy weight, as a locomotive engine or a loaded car rapidly passing over it, and acting with impulsive energy upon every part at different instants, it is obvious that no adequate resistance is offered by a truss composed of only the three series of timbers already described. Yet we find that such a truss has been used for a large proportion of the bridges that have been erected, sometimes with and sometimes without the addition of an arch, an appendage which, although it adds to the vertical strength, diminishes but little the effect of the force under consideration. No one who has had an opportunity of observing it can have failed to notice the great vibration produced in such bridges by the passage of a loaded vehicle. In long bridges, the undulations produced by the passage of a car can be felt at a distance of several spans.

563.



The remedy for this defect is obvious: it is only necessary to prevent the diagonals in the direction of the dotted lines from shortening, or in the direction of the braces from lengthening, and the upward force will be effectually resisted.

This requires either that counter-braces should be introduced in the direction of the dotted diagonals of the last figure, or that the braces themselves should be capable of acting as ties, or additional ties placed in the direction of the braces.

It follows, from the preceding exhibition of the effect of a variable load, that no bridge, either straight or arched, which is designed for the passage of vehicles, and particularly of railroad trains, should be constructed without counter-bracing or diagonal ties. It is only in aqueducts, when the load is always uniform, that they can with any propriety be omitted.

*Effects of Counter-bracing.*—The consideration of the action of counter-braces leads to some very singular but important results.

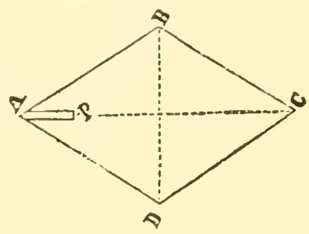
Let the truss be loaded with a weight so as to produce some deflection; it has been shown that the diagonals in the direction of the braces will be compressed, and in the direction of the counter-braces extended. Suppose that the extension of the last-named diagonals is sufficient to leave an appreciable

interval between the end of the counter-brace and the joint against which it abuts, and that into this interval a key or wedge of hard wood or iron is tightly introduced: it is evident that, upon the removal of the weight, the truss, by virtue of its elasticity, would tend to regain its original position; but this it cannot do, in consequence of the wedges at the ends of the counter-braces, which prevent the dotted diagonals from recovering their original length, and the truss is therefore forcibly held in the position in which the weight left it; the reaction of the counter-braces producing the same effect that was produced by the weight, and continuing the same strain upon the ties and braces.

The singular consequence necessarily results from this, that the passage of a load produces no additional strain upon any of the timbers, but actually leaves some of them without any strain at all.

To render the truth of this assertion more clear, we will confine ourselves to the consideration of a single rectangle, and suppose that the effect of the flexure caused by an applied weight has been to extend the diagonal $A\ C$ by a length equal $A\ p$, and to compress the brace $B\ D$ by an equal amount.

564.



The point $p$ will evidently be drawn away from $A$, leaving the interval $A\ p$. If a wedge be tightly fitted into this interval without being forcibly driven, it evidently can have no action upon the frame so long as the weight continues; but, upon the removal of the weight, it becomes forcibly compressed, in consequence of the effort of the truss, by virtue of its elasticity, to return to its former position. This effort is resisted by the reaction of the wedge, which causes a strain upon the counter-brace $A\ C$ sufficient to counteract the elasticity of the truss; and as no change of figure can take place, it follows that the brace $B\ D$ cannot recover its original length, and therefore continues as much compressed as it was by the action of the weight.

The effect of a weight equal to that first applied will be to relieve the counter-brace $A\ C$, without adding in the slightest degree to the strain upon $B\ D$.

As regards the effect upon the chords, it is evident that the strains are only partial, and tend to counteract each other. The maximum strain in the centre is estimated by the force which would be required to hold the half truss in equilibrium if the other half be removed; and this is dependent only on the weight and dimensions of the truss. In fact, if we examine the parallelogram $A\ B\ C\ D$, we find that the effect of wedging the diagonals will be to produce strains acting in opposite directions at $A$ and $B$, and destroying each other's effects; the strains produced by wedging any rectangle cannot therefore be continued to the next, and of course can have no influence upon the maximum forces at the centre.

As the vibration of a bridge is caused principally by the effort to recover its original figure after the compression produced by a passing load, it follows that, if this effort is resisted, the vibration must be greatly diminished, or almost entirely destroyed.

This accounts for the surprising stiffness which is found to result from a well-arranged system of counter-braces.

In proportioning the parts of a truss liable to a moving or unequal load, the case of greatest possible strain should be assumed, viz., that of the truss with its maximum uniform load with an additional load placed at the centre.

Let $W$ represent the weight of the truss and its uniform load, $w$ the greatest load ever applied at a single point, $p$ the length and $h$ the height of a panel, and $b$ the length of a brace.

The braces at the centre should be sufficient to bear the greatest strain ever to come upon a single point, and equals $\frac{w\,b}{2\,h}$.

The strain upon the end braces each equals $\left(\frac{W}{2} + w\right)\frac{b}{h}$.

The intermediate braces are proportioned as before in accordance with their position.

The tension on the rods is equal each to that of the adjacent brace toward the centre multiplied by the factor $\frac{h}{b}$.

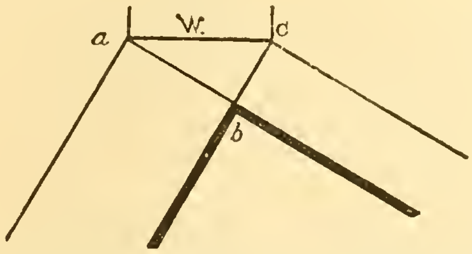
The strains upon the upper and lower chords are equal, being greatest at the centre, where they each equal $\left(\frac{W\,l}{8} + \frac{w\,l}{4}\right)\frac{1}{h}$. At the ends they each equal $\left(\frac{W}{2} + w\right)\frac{p}{h}$. If, however, the number of panels should be even, then the strain upon the lower chord will be in excess of that upon the upper throughout its whole length by the quantity $\frac{w\,p}{2\,h}$. The strains upon the counter-braces are small as compared with the other parts, being greatest at the centre, where it is advisable to make them equal to the middle braces. These should be permanently strained by adjustment while the truss is distorted by its maximum moving load applied at various points. By this means a perfect rigidity is secured, as previously referred to.

*Inclination of Braces.*—1. The braces must not be so long as to yield by lateral flexure.

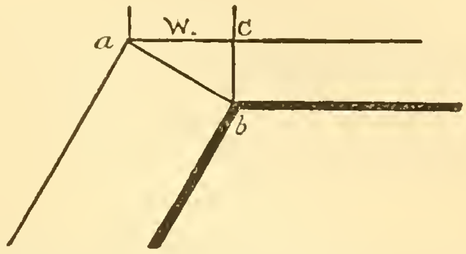
2. The chords being unsupported in the intervals between the ties, these intervals must be limited by the condition that no injurious flexure shall be produced by the passage of a load. On the other hand, as the ties approach each other, the angle of the brace increases; and when the intervals become small, the number of ties and braces is greatly increased, and with them the weight of the structure.

The true limit of the intervals can be readily determined when the size of the chords and the maximum load are known; for it should evidently be such that, when the load is at the middle, the flexure should not exceed a given amount.

565.



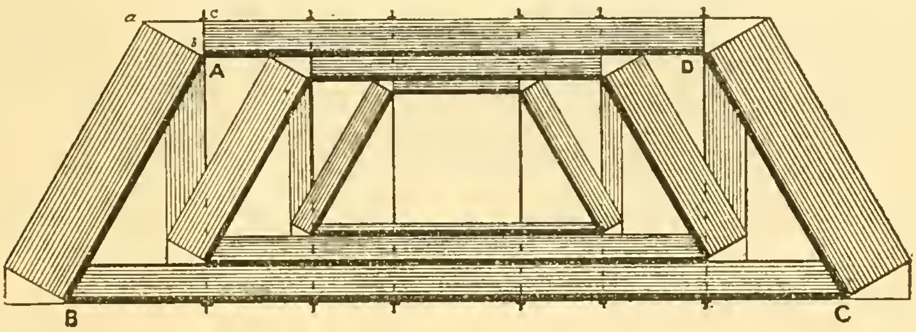

566.




The floor-beams, or roadway supports, should be sufficient to bear the greatest load ever applied at a single point.

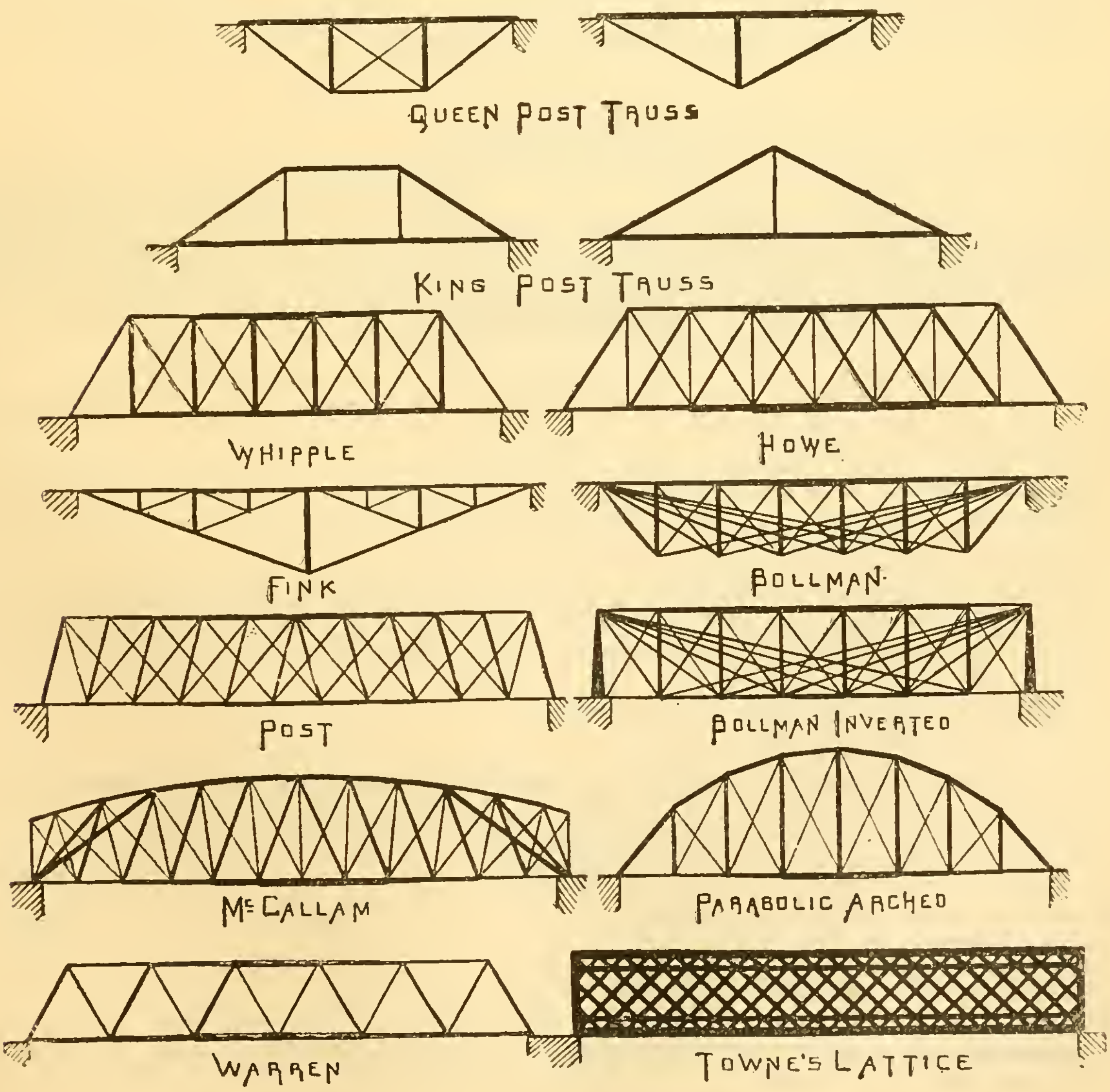
*Lateral Bracing.*—To prevent the lateral swaying of the bridge, principally caused by high winds,

567.




and to preserve the trusses in their proper relative positions under all circumstances, a light system of lateral bracing is introduced both at the top and bottom.

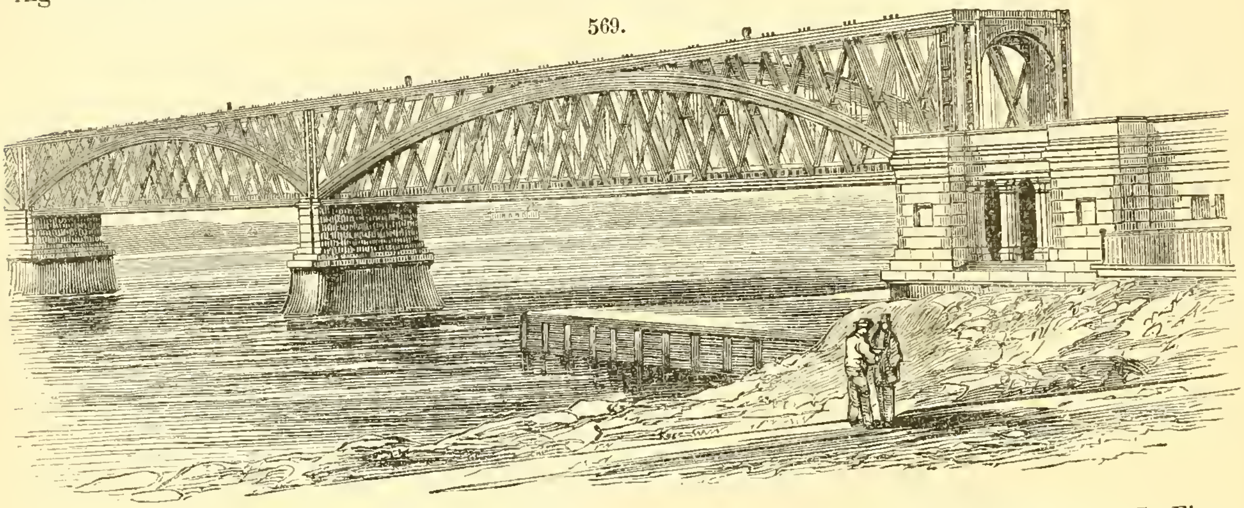
568.



*Camber.*—Because of the elasticity of the materials used in bridge-construction, it is the custom in practice to construct with a "camber," or slight rise at the centre. This is in proportion to the span, and, according to Trautwine, should not exceed 1 inch for every 50 feet in span.

To illustrate more plainly the strains to which the several members of a bridge-truss are subjected, a system of "graphic statics" may be employed, which was first practically used, so far as we know, by Mr. Dudley Blanchard in the construction of bridges about 1858. It consists in representing the measure of any force by a line at right angles with the direction of that force, and hence

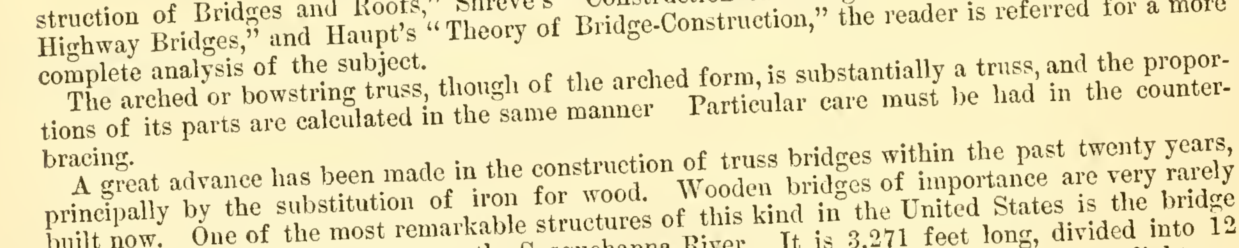
569.



represents by comparative breadths the relative strength required in any bridge member. In Figs. 565, 566, let a weight be applied at the joint $b$. Let its quantity be represented by the line $a\,c$; then completing the triangle $a\,b\,c$, by lines at right angles to the direction of the supporting members, the strains upon each member will be as the sides $a\,b$ and $b\,c$. Fig. 567 is an illustration of this method applied to a truss, in which the strains on the various members of the truss $A\ B\ C\ D$ are indicated by the breadth of such members.

Fig. 568 shows the most common forms of the truss bridge now in use, and their comparative merits are discussed in Merrill's "Iron Truss Bridges for Railroads," to which, with Wood's "Con-

570.



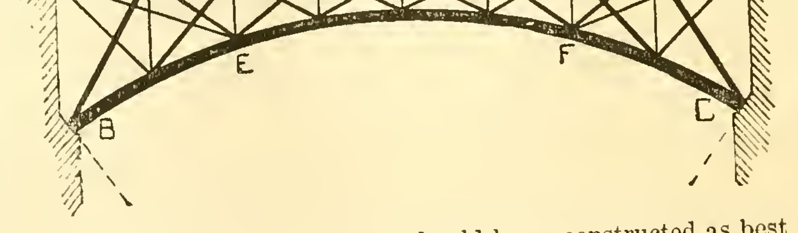
struction of Bridges and Roofs," Shreve's "Construction of Bridges and Roofs," Boller's "Iron Highway Bridges," and Haupt's "Theory of Bridge-Construction," the reader is referred for a more complete analysis of the subject.

The arched or bowstring truss, though of the arched form, is substantially a truss, and the proportions of its parts are calculated in the same manner Particular care must be had in the counter-bracing.

A great advance has been made in the construction of truss bridges within the past twenty years, principally by the substitution of iron for wood. Wooden bridges of importance are very rarely built now. One of the most remarkable structures of this kind in the United States is the bridge (Fig. 569) at Havre de Grace, over the Susquehanna River. It is 3,271 feet long, divided into 12 spans, resting upon granite piers. It is constructed on Howe's plan, and combines great lightness and strength.

A good example of a bridge on Fink's system is found in the railroad bridge (Fig. 570) over the Ohio River, at Louisville. Its length is 5,218⅔ feet, divided into 23 spans, supported by 24 stone piers. Its height is about 96½ feet above low water, and width about 27 feet.

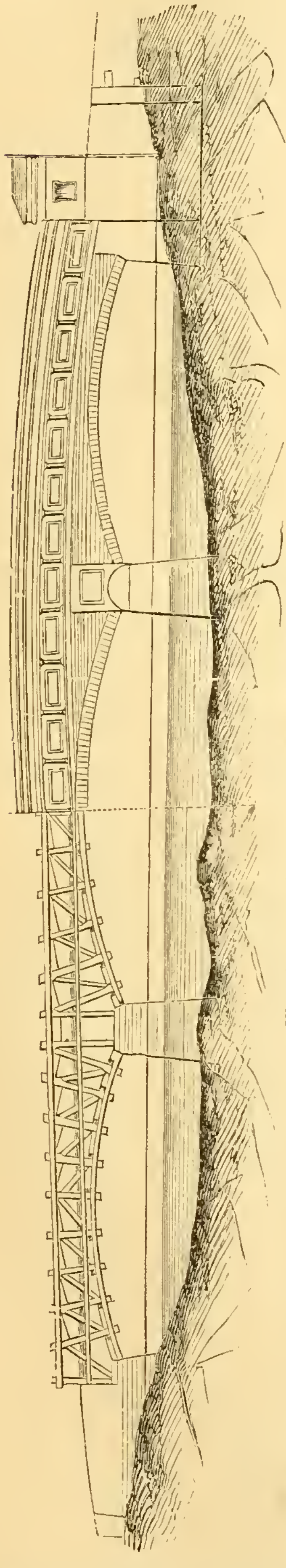
571.



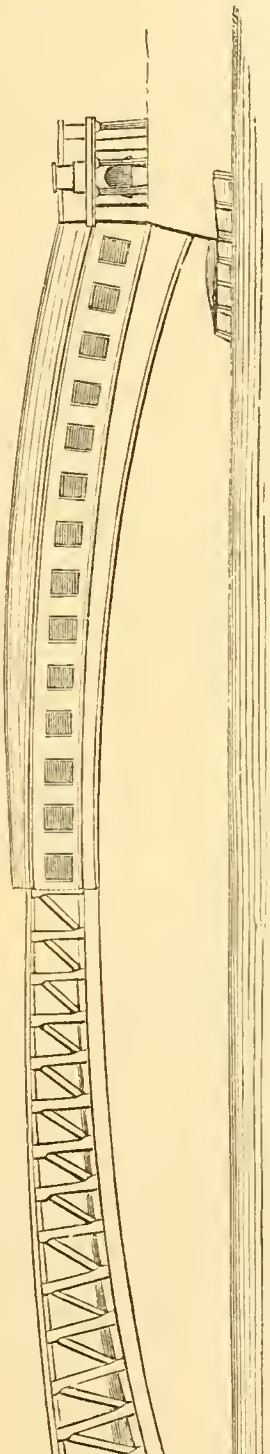

*Trussed-Arch Bridges* are those so framed that the entire weight is supported by the arch; the load, before acting upon it, being first distributed, and the direction of its pressure changed, by the intervention of a truss, Fig. 571. The truss should be so constructed as best to resist the tendency to rise when the arch is unequally loaded, and need be only sufficiently strong to


THE ST. LOUIS BRIDGE OVER THE MISSISSIPPI RIVER.

bear the moving load, and to firmly counter-brace the arch, the weight of the entire bridge itself being borne by the arch alone. For wooden bridges of long spans this is the best known form, and several remarkable structures of this type have been built. Figs. 572 and 573 show the construction of the two most noted American trussed arches of wood. The first consists of three arches, the centre one being of 195 feet span, and the other two of 150 feet each. The second has a single arch of 340 feet span, with only 20 feet rise—the largest wooden arch ever built.



572. Elevation of the Schuylkill Bridge. Longitudinal Section.



573. Elevation of the Upper Schuylkill Bridge. Longitudinal Section.

The recent completion of the St. Louis bridge, by Captain James B. Eads, is the crowning effort in bridge construction of this type. It consists of three arches, the centre one of which has a span of 520 feet, and the other two of 515 feet, and each with a rise of 60 feet. There are two main piers and two abutments, the foundation of one being 120 feet under water. The arches are formed with top and bottom chords in sections of steel tubes 16 inches in diameter, composed of staves 12 feet long, banded together by steel thimbles or couplings. These top and bottom chords, 12 feet apart, are connected by a triangular system of bracing, constituting an arched truss of great strength combined with extreme lightness.

*Lattice Bridges.*—One of the most simply-constructed types of bridges is the lattice bridge. If of wood, it may be built entirely of plank of uniform size; the braces crossing each other, generally at right angles, are fastened by a pin or "treenail" of hard wood, and the chords are so constructed as to break joint. The objections to this type of bridge are its liability to warp and the entire lack of proportion in its parts. The first objection is obviated by placing a double truss on each side of the bridge, so riveted together as to act as one. Its advantages are in the simplicity of its construction. They may also be built of indefinite length, and sawed off to suit the span required.

Lattice bridges have been successfully used in spans of as great lengths as 150 feet; and in Europe iron lattice bridges, with their parts in proper proportion, have been built of 300 feet span and upward. The most common form in this country is the "Towne;" but, as iron is now taking the place of wood, those types of bridge requiring less material are more generally preferred. As the proportions of the various parts depend upon the amount and character of the load a bridge is to sustain, this point should be carefully considered in designing each particular structure. The liability in practice is to underestimate this load for short spans. The following table gives the proportion of load to span, as recommended by a committee of the American Society of Civil Engineers, for highway bridges:

| SPAN. | POUNDS PER SQUARE FOOT. | | |
|---|---|---|---|
| | For City and other Bridges, when Travel is heavy and frequent. | For Towns and Villages, and Districts having well-ballasted Roads. | Ordinary Country Bridges—Travel infrequent and Loads light. |
| 60 feet and under. | 100 lbs. | 100 lbs. | 75 lbs. |
| 60 to 100 feet. | 90 " | 75 " | 66 " |
| 100 " 150 " | 80 " | 66 " | 50 " |
| 150 " 200 " | 70 " | 60 " | 50 " |
| 200 " 300 " | 66 " | 50 " | 40 " |
| 300 " 400 " | 60 " | 50 " | 35 " |

And for railroads as follows:

| SPAN OR PANEL. | Pounds per Lineal Foot of Track. | SPAN OR PANEL. | Pounds per Lineal Foot of Track. |
|---|---|---|---|
| Under 12 feet. | 6,000 lbs. | Under 75 feet. | 3,000 lbs. |
| " 15 " | 5,500 " | " 100 " | 2,750 " |
| " 20 " | 5,000 " | " 150 " | 2,500 " |
| " 25 " | 4,500 " | 150 to 175 " | 2,500 " |
| " 30 " | 4,000 " | 175 " 200 " | 2,400 " |
| " 50 " | 3,250 " | 200 " 300 " | 2,250 " |

*Suspension Bridges* are best adapted for long spans, and have been successfully constructed with spans more than twice as long as any other form of bridge. These bridges are usually constructed with chains or cables passing over towers, with the roadway suspended beneath. Each end of the chains or cables is securely anchored. On the towers the cables rest in saddles, which are movable, so that the strains do not tend to overturn the towers.

The deflection of the cable usually employed is between one-tenth and one-fifteenth of the span.

The unloaded cable assumes the form of the catenary; but loaded with the suspenders and the road-bed, it approaches the parabola.

The tension upon a cable is approximately obtained by the formula $T = \frac{w}{4x}\sqrt{4x^2 + y^2}$; in which $w$ represents the weight equally distributed, $x$ the deflection of the cable, and $y$ the length of the one-half span.

The length of the cable equals $2\sqrt{y^2 + \frac{4}{3}x^2}$.

A bridge constructed with the road-bed supported only by vertical suspenders would lack stiffness, as it would be deficient in that which corresponds to counter-bracing in truss bridges; and thus some discredit has attached to the earlier bridges of this type, which were lacking in this respect.

By trussing the road-bed and using inclined stays extending from the top of the towers, and partially supporting the roadway for some distance out from the tower, a sufficient degree of stiffness is obtained.

Iron suspension bridges of large span are of comparatively modern date. The first one built in England was by Sir Samuel Brown, across the Tweed at Berwick, in 1819; its span was 449 feet. The longest span in Europe is at Fribourg, in Switzerland, built by M. Chaley in 1831–'4. It has a span of 870 feet, and is 174 feet above the river. Its cables are made of iron wire.

One of the most important bridges of this class in the United States is the Niagara Falls Suspension Bridge, constructed by John A. Roebling, C. E. This bridge has a span of 821 feet 4 inches, from centre to centre of towers. Its form is a slightly-curved hollow beam or box, of a depth of 18 feet; width of bottom 24 feet, and of top 25 feet. The lower floor is used for common travel, while the upper is appropriated to railway business and sidewalks. The two floors are connected by two trusses of a simple construction, so arranged that its resisting action operates both ways, *up* as well as *down*. The suspenders are 5 feet apart. The beams of the upper and lower floors are connected by posts arranged in pairs, leaving a space between for the admission of the truss-rods, which extend each way to the fourth pair of posts at an angle of 45°. These rods therefore cross each other and form a diamond work. They are 1 inch diameter, their screw ends 1¼ inch.

There are 4 cables of 10 inches diameter, each composed of 3,640 wires of small No. 9 gauge, 60 wires forming one square inch of solid section, making the solid section of each cable 60.40 square inches, wrapping not included. Each of the four large cables is composed of seven smaller ones, which are called *strands*. Each strand contains 520 wires; one of these forms the centre, the six others being placed around it; the ends of the strands are passed around and confined in cast-iron shoes, which also receive the wrought-iron pin that forms a connection with the anchor chains. During the wrapping process the whole mass of wire was saturated with oil and paint, which, together with the wrapper, will protect the cables effectually against all oxidation. There are 64 diagonal stays, of 1⅝-inch diameter rope, above the floors, equally distributed among the four cables. They are fastened to the suspenders by small wrappings, so as to form straight lines; they are not continued over the towers to the anchorage, but are secured to the saddles, and allowed to move with them. To the under side of the lower floor 56 stays are attached, which are anchored in the rocks

below, and occupy positions calculated to insure against horizontal as well as vertical motions. The anchorage of the back chains was formed by sinking 8 shafts into the solid limestone rock that here composes the uppermost stratum of the cliffs. Three of the pits on the New York side are sunk to a depth of 25 feet. The fourth one, southeast, was sunk only 18 feet, on account of the great influx of water and difficulty of baling. The surface of the rock on the Canada side being 10 feet higher than on the New York side, the depth of the shafts was increased that much, and the height of the towers above reduced in proportion. Each shaft has a cross-section of 3 × 7 feet, enlarged at the bottom to a chamber of 8 feet square. The anchor chains are composed of 9 links, all of which are 7 feet long, except the uppermost or last one, which is 10 feet. The first or lowest link is composed of 7 bars, 7 × 14 inches, and is secured to a cast-iron anchor plate by a pin of 3½ inches diameter ground upon its seat. The next link is composed of 6 bars of the same size, and 2 half bars on the outside. The aggregate section of each is 69 superficial inches; from the fourth link up, the link on the chain curves, and the section is gradually increased to 93 superficial inches.

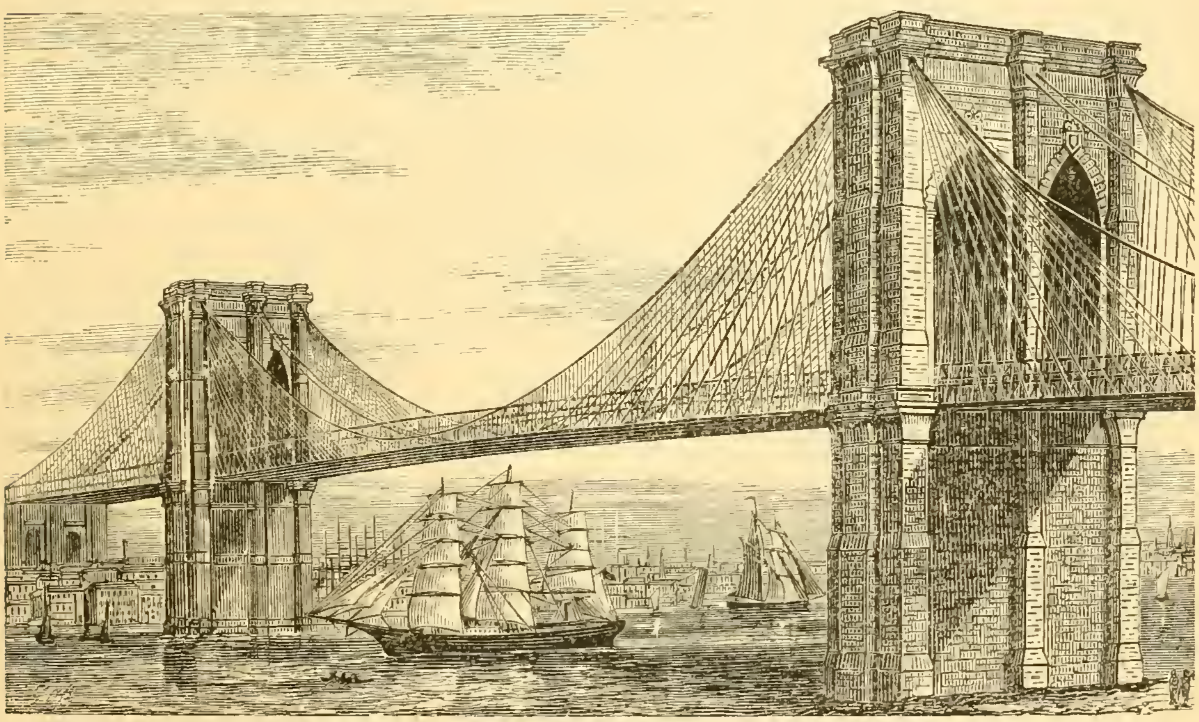
On the top of each column a cast-iron plate was laid down, well bedded in cement, 8 feet square and 2½ inches thick, and strengthened by three parallel flanges for the reception of two independent saddles. Each saddle rests on ten cast-iron rollers, 5 inches in diameter and 25½ inches long, placed close together. The ordinary pressure upon each tower, being about 500 tons, makes each roller bear 25 tons. These rollers admit of a slight movement of the saddles, whenever the equilibrium between the land and the suspension cables is disturbed, either by changes of temperature or by passing trains.

The table on page 272 gives the leading characteristics of the most celebrated long-span bridges of the various types, showing more particularly the comparative lengths of their maximum spans.

The use of steel wire for the cables has made still longer spans possible.

The "East River Suspension Bridge," Fig. 574, between the cities of New York and Brooklyn,

574.



designed by John A. Roebling, and built by his son Colonel W. A. Roebling, has its cables composed of steel wire, having a strength of 160,000 lbs. per square inch; whereas iron wire would sustain but little more than one-half that amount, and iron bars less than one-third. This bridge is supported by four cables, each 15½ inches in diameter. The main span is 1,595½ feet, and the side spans 930 feet each, making the suspended portion 3,455½ feet in length. This, with the approaches —2,533½ feet—make a total length of 5,989 feet. The height of the roadway above high tide is 135 feet, the height of the towers 272 feet, and the width of the bridge 85 feet.

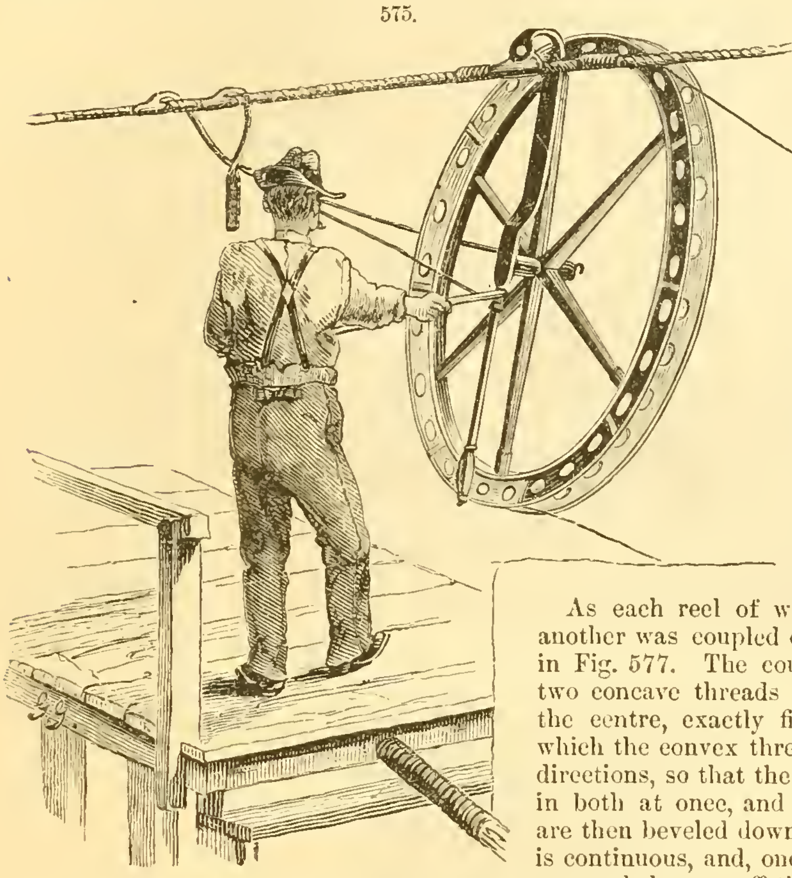
The mode of constructing the wire superstructure of this bridge was as follows:

The wire came from the factory in large coils, some 5 feet in diameter. These were dipped in oil, dried in the air, and dipped again and again until a moderately thick coat of hardened grease had changed their bright zinc-lustre into a dirty yellow; then they were carried up on the top of the anchorage, reeled off on large wooden drums, and from these last they were paid off as required. The carrier-rope was simply an endless wire cable, which started from the Brooklyn anchorage, passed over the two piers in turn, then to the New York anchorage, on top of which are two horizontal pulleys, around which it led, then back to Brooklyn, and finally, after passing around an immense horizontal engine-driven drum, the ends were joined. One part of this carrier-rope carried wire for one inner main cable, the other part for the corresponding outer main cable. On each part was attached a traveler-wheel, which is represented in Fig. 575. This was a light wheel of wood and tin, turning in bearings suspended from the rope; braces were arranged in

| LOCATION. | Length. | Longest Span. | Material. | Type. | Character. | Designer. | REMARKS. |
|---|---|---|---|---|---|---|---|
| | Feet. | Feet. | | | | | |
| Waterloo Bridge, London | ...... | 120 | Stone | Elliptical arch | Highway | Rennie | |
| Cabin John, Washington aqueduct | ...... | 220 | " | Circular " | Aqueduct | Meigs | |
| Omaha bridge | 2,750 | 250 | Iron | Post truss | Railway | American Bridge Company | |
| Leavenworth bridge | 1,000 | 340 | " | " " | Railway and highway | " " " | |
| Poughkeepsie | 4,595 | 525 | " | Truss | Railway | " " " | In process of construction. |
| Fairmount | ...... | 348 | " | " | Railway and highway | Keystone " " | |
| Newport and Cincinnati | ...... | 420 | " | Linville truss | Railway | ...... | |
| Susquehanna | ...... | 307 | " | Truss | " | Phœnix Iron and Bridge Company | |
| Upper Schuylkill | 340 | 340 | Wood | Segmental arch | Highway | Wernwag | Destroyed by fire. |
| St. Louis | 1,550 | 520 | Steel | " " | Railway | ...... | |
| Pittsburgh | 1,245 | 800 | Iron | Suspension | Highway | American Bridge Company | |
| Niagara | ...... | 821 | " | " | Railway and highway | John A. Roebling | |
| Fribourg, Switzerland | ...... | 859 | " | " | Highway | Chaley | |
| Wheeling | ...... | 1,010 | " | " | ...... | Charles Ellet, Jr. | Destroyed by tornado. |
| Cincinnati | 2,220 | 1,057 | " | " | Highway | John A. Roebling | |
| New Niagara | ...... | 1,229 | " | " | " | ...... | |
| Victoria bridge | 10,500 | ...... | " | Tubular | Railway | Stephenson | |
| Conway " | 400 | 400 | " | " | Highway | " | |
| Britannia " | 1,378 | 459 | " | " | " | " | |
| Hammersmith | ...... | 422 | " | Suspension | " | Tiernay Clark | |
| Menai Strait | ...... | 580 | " | " | " | Telford | |
| East River | 5,989 | 1,595 | Steel | " | Highway and railway | John A. Roebling | |

connection with it to prevent oscillation. Over this wheel the bight of the wire to be laid was passed. One end of the wire was fastened, the other went to the reel; then the drum of the carrier-rope turned, and the wheel, attached to the latter, started on its journey. The wire gradually unwinding from the reel, the wheel traveled on over the piers, and finally came to rest on the New York anchorage. There the bight of wire was slipped out of its groove and put around a massive iron shoe (Fig. 576), and then the motion of the carrier-rope was reversed, and the empty wheel returned. At the same time another wheel, carrying another bight of wire for the second cable, started across. And thus the work continued, a filled wheel constantly going out and an empty one returning—two strands of two different cables being thus simultaneously made.

575.

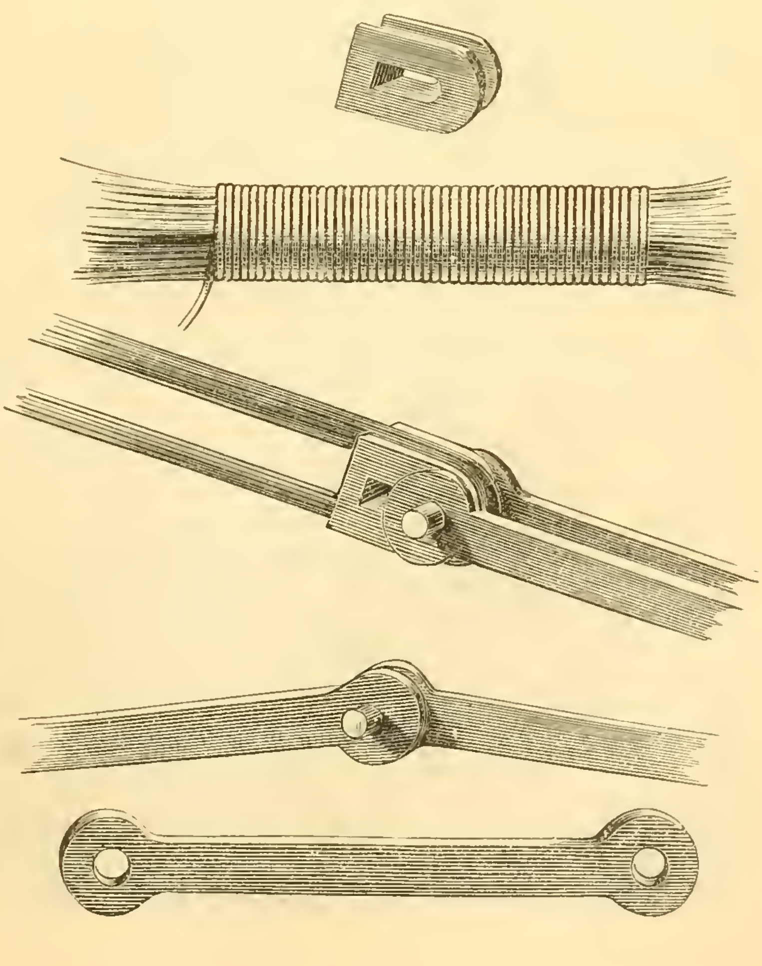


As each reel of wire was exhausted, the end from another was coupled on by means of the device shown in Fig. 577. The coupling is a hollow cylinder, with two concave threads in inverse directions meeting at the centre, exactly fitting the ends of the wires, in which the convex threads are cut, naturally in opposite directions, so that the same turn of the coupling screws in both at once, and the sharp edges of the cylinder are then beveled down. Thus the wire of each strand is continuous, and, once fastened at the Brooklyn end, was reeled on or off till the whole strand was laid.

After each wire was laid it was brought to the same curvature as the wire preceding it. To do this, after the carrier had passed the wire from the anchorage over the saddle at the top of the pier, it was stopped, and a tackle was attached. To ascertain the requisite amount of distance to be raised or lowered from the top of the pier to the anchorage, flagmen were stationed on the cradles, of which there were three between the piers, who reported, by means of prearranged moves of their flags, to the flagman on the top of the pier, the amount of deflection there was in the wire, and it was accordingly raised or lowered, as demanded.

When the requisite number of wires was laid to form a strand, an apparatus called a "buggy" was attached to this strand, and made to travel upon it. The workmen in the buggy gathered the wires into a bundle, and retained them with a pair of peculiarly-shaped tongs, and temporarily bound the strand with wire at intervals of about 28 inches. When 19 strands of the cable were finished and placed side by side, the wrappings about the strands were removed, and the entire 5,700 wires were bound together by encircling wires, so as to form a solid cable. After each strand was bound, the yoke, seen suspended above the massive saddle, Fig. 578, upon which the strand rests, was lowered; the clevises, of which there are four, were removed, and, clasping the

576.



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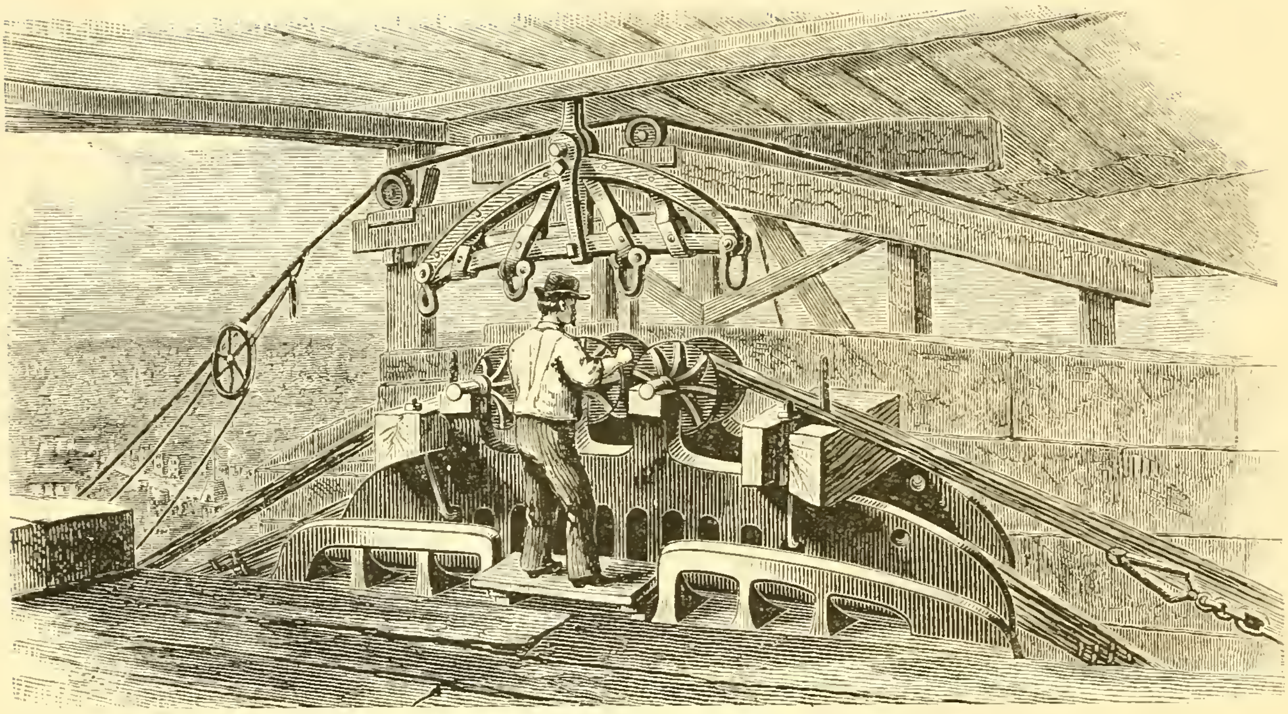

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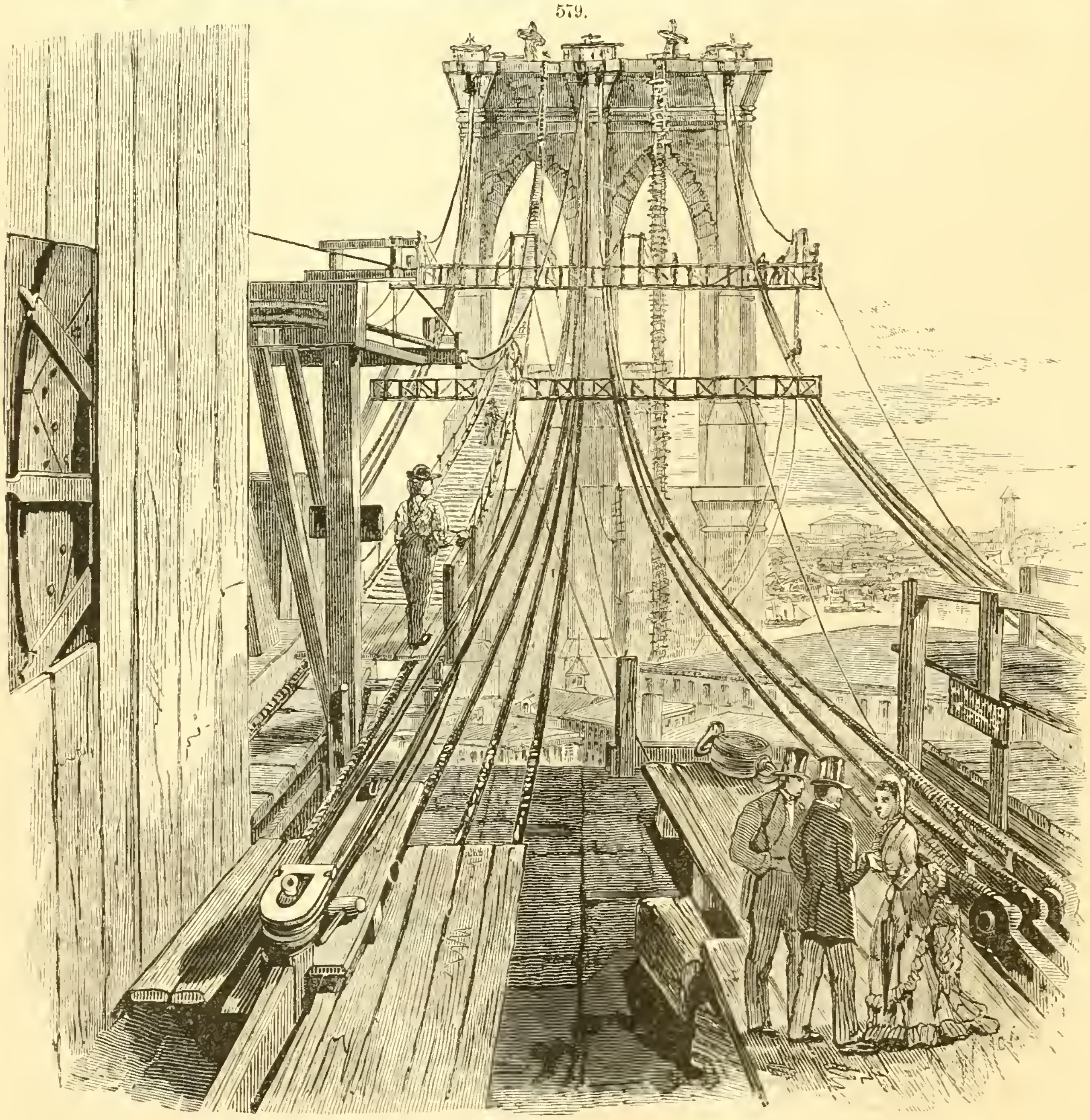

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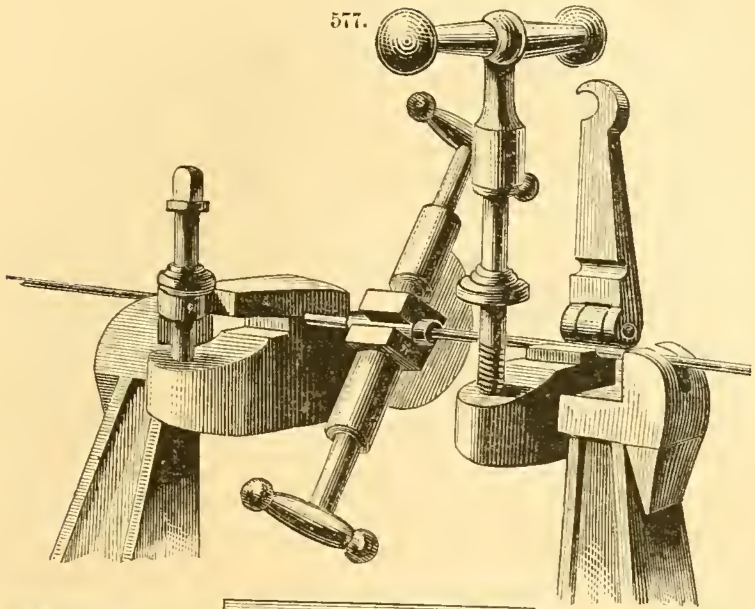

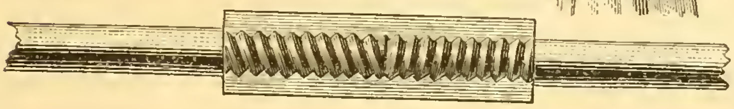

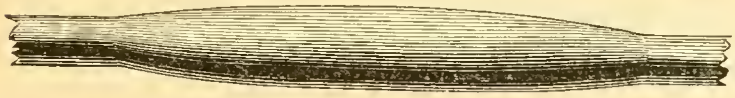

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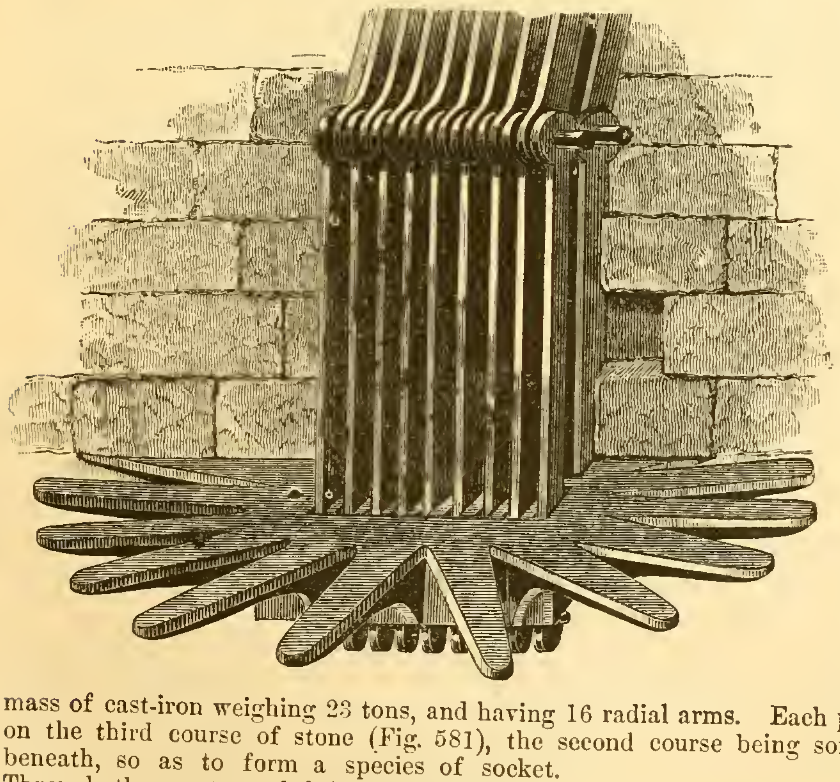


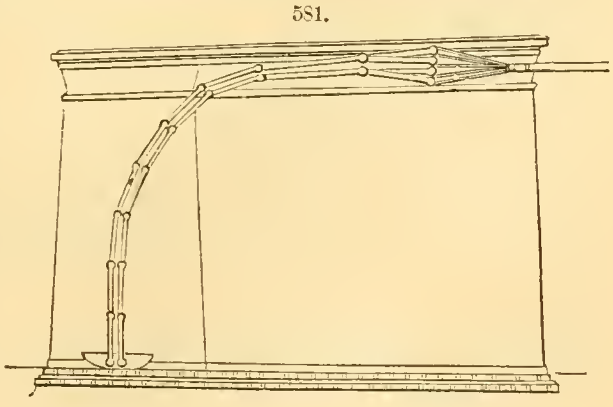
strand, were bolted in their former places. The capstan nut, seen at the top of the framework over the yoke, was rotated; and as it revolved on the screw to which the yoke was suspended, it raised both yoke and strand until the latter was clear of the pulleys on the saddle. The pulleys were then removed, and the strand lowered away into its bed in the saddle underneath the pulleys. The clevises on the yoke were then uncoupled, the yoke raised out of the way, the pulleys put in place, and another strand was laid similar to the previous one.

The saddles, to which reference has been made, are four massive castings resting on the top of each pier, and each one holding in its embrace one of the cables. The pulleys over which the strand passed were used for convenience in laying the strand, and were removed entirely when the cable was completed and placed in its saddle. To allow for the difference in unequal contraction and expansion of the cable from anchorage and pier, and between the piers, the saddle rests upon a series of iron rolls, which allow of a change of its place, as the force of contraction or expansion is brought to bear upon it.

Fig. 579 represents the bridge while in process of building, and shows the location of the cradles above referred to.

Figs. 580 and 581 represent a section of one anchorage, and a perspective view of one of the massive anchor-plates of the East River Bridge. In each anchorage there are four of these anchors, each being a mass of cast-iron weighing 23 tons, and having 16 radial arms. Each plate is embedded in concrete on the third course of stone (Fig. 581), the second course being somewhat thinner immediately beneath, so as to form a species of socket. Through the apertures left in the centre of the plates the first set of bars for the chains is placed. Each chain consists of 10 sets of links, and two chains lead from each plate. The corresponding links of each pair of chains contain together about 19 bars. A glance at Fig. 581 will show that the tendency of the cables is to upset the anchorage on its front edge. The strain on each cable is estimated at 1,833 tons.

581.

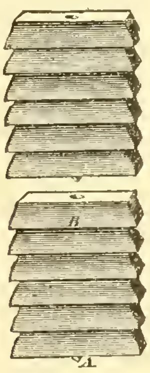


*Works for Reference.*—"Les Constructeurs des Ponts du Moyen Age" (descriptions of remarkable bridges of the 12th and 13th centuries), Brouquier-Rouie, Paris, no date; "Œuvres," Perro-

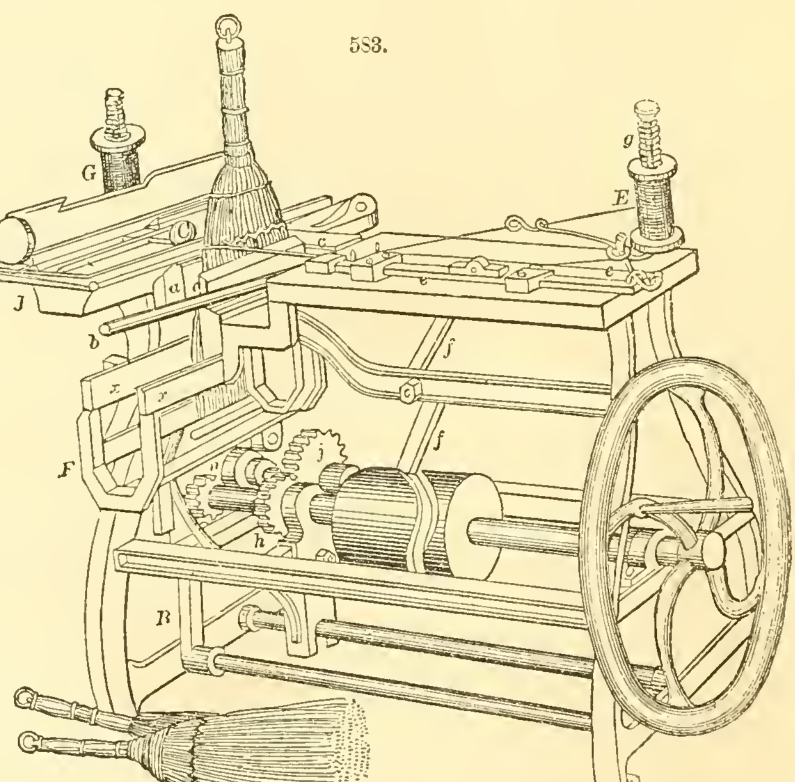
net, 1788; "A Treatise on Bridge Architecture," Pope, 1811; "Traité des Ponts," Gauthey, Liége, 1816; "On Vaults and Bridges," Ware, 1822; "Les Ponts Suspendus," Navier, Paris, 1830; "Theory, Practice, and Architecture of Bridges," Hann and Hoskens, 1843–'50; "The Theory, Practice, and Architecture of Bridges," Weale, London, 1843; "On Bracing," Bow, London, 1851; "Suspension Bridge across the Danube" (Pesth), W. T. Clark, London, 1852; "Des Ponts Suspendus," Boudsot, Paris, 1853; "Military Bridges," Douglas, London, 1853; "Sur l'Etablissement des Arches de Pont," Yvon Villarceau, Paris, 1853; "General Theory of Bridge Construction," Haupt, New York, 1853; "On Iron Bridges and Girders," Humber, 1857; "Traité théorique et pratique de la Construction des Ponts Métalliques," Molinos and Pronnier, Paris, 1857; "Des Ponts et Viaducts en Maçonnerie," Roy, 1857; "On the Construction of Iron Bridges," Latham, 1858; "Construction of the Great Victoria Bridge, Canada," London, 1860; "Sammlung eiserner Brücken-Constructionen," Von Klein, Stuttgart, 1863; "On Iron Bridge Construction," Humber, 1864; "Military Bridges," Haupt, New York, 1864; "De divers Systèmes de Ponts en Fer," Gaudard, Paris, 1865; "On Strains in Girders," Stoney, London, 1866–'69; "Berechnung eiserner Bogenbrücken," Fränkel, Hanover, 1867; "Theory of Strains in Girders," Shields, 1867; "On Long-span Railway Bridges," Baker, Philadelphia, 1867–'70; "On Wrought-iron Bridges and Roofs," Unwin, 1869; "Long and Short Span Railway Bridges," Roebling, New York, 1869; "Strains in Girders," Humber, 1869; "Iron Railway Bridge at Quincy, Ill.," Clarke, New York, 1869; "The Kansas City Bridge," Chanute and Morison, New York, 1870; "International Bridge constructed across Niagara River," Gzowski, Toronto, 1873; "An Elementary and Practical Treatise on Bridge-Building," Whipple, New York, 1873; "On the Strength of Bridges and Roofs," Shreve, New York, 1873; "Works in Iron," Matheson, London, 1873; "Proportions of Pins used in Bridges," Bender, New York, 1873; "Manuel de l'Ingénieur des Ponts et Chaussées," De Bauve, Paris, 1873; "Bridge and Tunnel Centres," McMaster, New York, 1875; "Continuous Revolving Bridges," Herschel, Boston, 1875; "Iron Truss Bridges for Railroads," Merrill, New York, 1875; "Graphical Method for Analysis of Bridge Trusses," Greene, New York, 1875; "Theory and Calculation of Continuous Bridges," Merriman, New York, 1876; "Properties of Continuous Bridges," Bender, New York, 1876; "Iron Highway Bridges," Boller, New York, 1876; "A Treatise on the Construction of Bridges and Roofs," Wood, New York, 1876; "Les Ponts de l'Amérique du Nord," Conrolle, Paris, 1878; "Bridges: an Elementary Treatise on Construction," Jenken, Edinburgh, 1878. See also numerous papers in the "Transactions" of the American Society of Civil Engineers, Institute of Civil Engineers (British), Society of Engineers (British), and Institute of Mechanical Engineers (British), and in the *Annales des Ponts et Chaussées;* also articles on bridges in the "Encyclopædia Britannica," 9th edition, Spon's "Dictionary of Engineering," Appletons' "American Cyclopædia," and *Van Nostrand's Eclectic Engineering Magazine;* also the works on civil engineering of Moseley, Mahan, Rankine, and others. W. H. P.

BROACH. A tool formed as shown in Fig. 582, and employed to cut out mortises or slots with great accuracy and expedition. The work is chucked to the table of a press, and a succession of the broaches of increasing width and thickness are forced through the work. In the centre of the head of each broach is a conical recess, and similarly located in the bottom of each is a conical projection, so that each successive broach may be guided centrally by the projection of the one following fitting

582.



583.



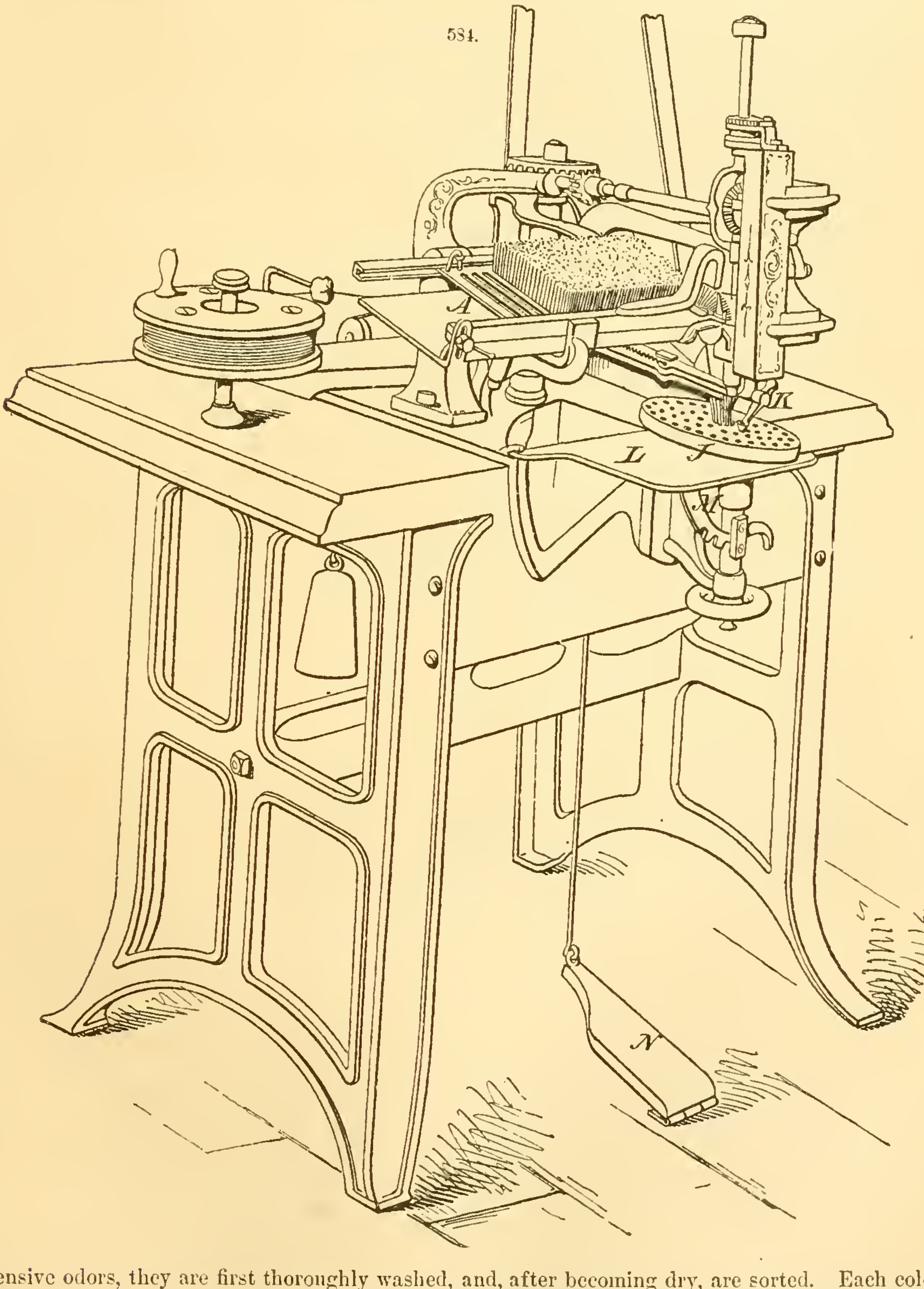

into its recess. The head of each broach is formed of rectangular shape and tapered to fit into a rectangular recess provided in the end of the ram of the press to receive it. If the mortises are of large dimensions, the broaches are made first to operate on the sides only. Other broaches are subsequently forced through to cut out the ends and the corners of the mortises. J. R.

BROOMS are usually made from broom-corn, which is a species of doura or sorghum. Fig. 583 is a machine for pressing a bunch of broom-corn into shape for a broom, and sewing it in its flattened form. The broom is placed between jaws *a a*, closed by

an eccentric $c$ operated by lever $b$. The machine being set in motion by the rotation of the cam-wheel $A$, the cam-groove of the latter, actuating the lever $f$, forces forward the needle-bar $e$, thus driving the needle with its thread through the broom, above the twine wound around the latter. The shuttle $C$, operated by lever $B$, acting on the opposite side of the broom in conjunction with the needle, forms the stitch. This being done, the reverse movement of the needle-bar withdraws the needle; the eccentric $h$ lifts the jaws $a$ $a$, so that the next stroke of the needle carries the stitch below the binding twine, the jaws being meanwhile moved along the guides $x$ $x$ by means of a pawl, operated by a cam $n$ on a supplemental shaft moved by gears $h$ $j$, the pawl gearing with a ratchet formed at the under side of the outermost of the jaws $a$ $a$. The next outward movement of the needle, the jaws being of course again lowered, carries the stitch above the binding twine. In this manner the stitches are formed alternately above and below the binding twine, the distance apart of the stitches corresponding to the intermittent feed given, as just described, to the jaws $a$ $a$ upon their supporting guides $x$ $x$. The needle is supplied from the spool $E$, which has a tension-spring $g$.

BRUSH-MAKING. Bristles, as they come off the hog's back, are covered with dirt and a sort of gummy substance, that make them very unpleasant to handle. To rid them of these, and also of

584.




offensive odors, they are first thoroughly washed, and, after becoming dry, are sorted. Each color is placed by itself, and these grades are known to the operative as black, gray, yellow, white, and lilies; the last are a kind almost transparently white, and of exceedingly fine texture. The sorting process

also includes the distribution of the bristles in such a way that the collection shall be of equal length. Besides, the root-ends of the bristles must be kept together. The next process is to comb them. By this means they are rendered elastic, and receive a beautiful polish. After being again washed, they are ready for the use of the brush-maker.

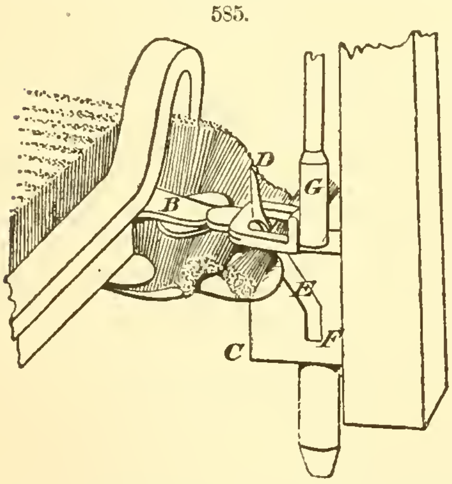
Brushes are divided into two general classes, known as single brushes and compound brushes. The former are distinguished by one tuft or bundle of bristles. But a hair-brush belongs to the second order, because of its collection of bristle bundles.

Brushes are also made of the soft hair of animals, such as the sable, badger, and squirrel. Of such are the small paint-brushes used for water-colors. Other kinds of brushes are made of the roots and fibres of certain tropical plants, of horse and goat hair, old rope, cocoanut fibre, broom-corn, the fibre of whalebone, and even of spun glass.

Small paint-brushes are manufactured as follows: The hairs are first cleaned in alum-water, and subsequently soaked in warm water, dried, combed, and assorted. The brush-maker takes sufficient of the prepared hair to fill a small groove which holds them tight; while thus placed the root-ends are wound tightly with thread. The soft hairs are then arranged so as to form a point, without leaving a blunt or scraggy end when the brush is wet. This part of the business is generally performed by women or boys, as it requires a very delicate touch to arrange them properly. The handles are made from quills, which are soaked in hot water to expand them sufficiently. When the brush is ready the hairs are inserted, point first, in the large end of the quill. Then, by a contrivance peculiar to the trade, the brush is drawn through until the tied part is brought down to the small end of the quill. This completes the process, and when the quill gets cold it contracts to its original dimensions, and thus secures the brush part very tightly. The quills used for handles are of various sizes, and are obtained from geese, turkeys, ducks, pigeons, and even smaller birds, such as quails, larks, etc. The size of the handle is always proportioned to the size of the brush, and the purposes for which it is made. When the quantity of hair or bristles is larger than can be used to advantage with quills, the bunch of material is put into tin tubes with wooden handles. Even these, when too large, are placed in other handles made of wood, with perforated holes. Bundles of bristles designed for this purpose are secured with strong cord, which has been dipped in glue. A scrubbing-brush is a compound brush, and has holes bored in rows along its entire length. Into these holes bristles are inserted, after first having been dipped at one end into melted pitch. When properly secured, they remain there in spite of hard usage and hot water. Some brushes are very costly, while others are sold at a mere trifle. Of the former are elaborately carved hat-brushes, hair-brushes, velvet-brushes, clothes-brushes, tooth-brushes, nail-brushes, etc. Besides these we have the more common kinds of shoe-brushes, scrubbing-brushes, shaving-brushes, and other varieties, by far too numerous to mention.

Hair-brushes are of the most complicated manufacture. Holes large enough to admit the bunches of bristles are bored all over the back of the brush part way through, while much smaller ones are bored clear through. A tuft of bristles is doubled over a piece of fine wire. After being thus properly secured, the workman puts the wire through the small hole, and draws the bristles up as far as possible in the big hole. The wire is then carried on to the next hole, until the whole surface is covered over with connecting lines of wire and tufts of bristles. When thus far completed, the bristles are cut off evenly, and a fancy back is glued on to hide the wire, and give the brush a more finished appearance. Tooth and nail brushes are made in a similar way, but the holes where the wire is secured are made on the side, and corked up with small plugs of ivory or bone. Some brushes have handles of perfumed wood, and are ornamented considerably, at heavy expense. Brushes made of spun glass are used in acids, which will destroy ordinary brushes.

585.

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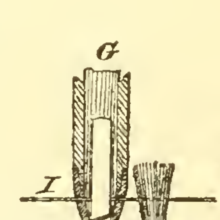


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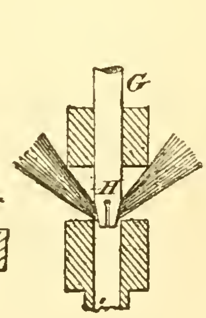



Brushes are sometimes backed with a hard rubber composition, which is made in a die composed of two parts, the cover and the base. In the cover there is cut whatever device or ornament the back of the brush is intended to receive. In the base there are holes of a depth to correspond with the length of the tufts which are exposed after the brush is finished. The process begins by filling the holes with bristles, which have been cut by a gauge as much longer than the depth of the holes as it is desired to have them penetrate the back of the brush. The upper part of the die is then covered with a sufficient quantity of plastic rubber composition; then it is adjusted to its fellow, and the die is placed in a screw-press and subjected to great pressure. After hardening, which takes place in a few minutes, the brush is removed.

In Figs. 584, 585, 586, and 587 is represented Woodbury's machine for inserting bristles in brush-backs. The first operation is the filling of the comb *A* with bristles. The comb is inserted in guide-ways, and is actuated by an intermittent traverse motion, which, whenever the bristles are all removed from one of the spaces, moves the comb along the distance of one tooth and one space to bring another filled space into position. Whenever one comb is emptied another is made to follow it in

the same guideways, the empty one being taken out at the opposite end of the guideways from that in which it was inserted. As the comb is actuated in the manner described, each space is brought successively to correspond with and form a part of a twisted way or channel *B*, Fig. 584. An ingenious combination of devices then forces the bristles, as they are wanted, down through this twisted channel, holding them all the time at the middle, and bringing them at last into a horizontal position as shown in Fig. 584. At the end of the channel the plate which forms the upper wall is bifurcated, the ends of the bifurcations being turned up as shown. Between these bifurcations reciprocates vertically a device consisting of a body *C*, which tapers off in front to a point *D*, and is slotted obliquely and vertically, the oblique portion of the slot terminating at *E*, and the vertical portion at *F*. The lower portion of this piece is a hollow cylinder, the end of which, descending, comes just flush, but does not enter the hole in the brush-back where the bunch of bristles is to be inserted, one bunch being put in at every descent of this part of the machine, which, from its resemblance to a hook, we shall call by that name as we proceed. As the hook rises, it forces its point between the proper quantity of bristles for a bunch, and these, being obliged to move along the inclined portion *E* of the slot in the hook, arrive at the bottom of the vertical portion *F*. Here they are acted upon by the plunger *G*, Fig. 585, the end of which has two slots crossing each other at right angles when viewed endwise. One of these slots receives the bunch of bristles as shown in Fig. 585. The other slot, *H*, is of a width only to allow the passage of a wire which is destined to bind the bunch together and secure it in the block. The plunger is caused by ingenious mechanism to descend till it doubles the bristles into a loop in the middle. Other mechanism then unwinds the binding wire *I* from a reel, straightens it, and passes the proper length through the slot *H*. The wire is then cut. The plunger descends, receiving a rotary motion on its vertical axis, which winds the wire spirally by forcing it into the thread of a nut contained in the lower end of the hollow cylinder, fastening it around the doubled end of the bunch of bristles. This spirally wound wire is destined to be a screw-thread for the bunch of bristles as the latter is screwed into the hole *J*. The lower end of the wire acts as a tap cutting a female screw in the block, and the upper end serves as a pawl to prevent the removal of the bunch by unscrewing. The bunch is thus held with great strength. The machine inserts bristle, hair, tampico, or other material used for brushes, in wood, leather, rubber, bone, ivory, and even glass. Its capacity is about 600 brushes of 60 knots each per day. The Woodbury Brothers, inventors of the apparatus, have also devised a machine which fills the combs with bristles; another which, by the rotation of a cylinder having curved knife-blades, forces the ends of the bunches in the finished brush against a stationary blade, and so trims all to an even length; and a boring machine which uses a two-spurred bit, and makes the holes for the bunches with great rapidity. (See *Scientific American*, xxxviii., 351.)

BUCKET. See MINE APPLIANCES.

BUDDLE. See CONCENTRATING MACHINERY.

BUHL-WORK, or BOOL-WORK. These terms appear to be corrupted from Boule, the name of the original inventor, and now refer to any two materials of contrasted colors inlaid with the saw. In France this kind of inlaid work is called *marqueterie*. It consists in representing flowers, animals, landscapes, and other objects, in their proper tints, by inlaying. It also includes geometrical patterns composed of angular pieces laid down in succession, as in ordinary veneering, and is chiefly used in ornamenting cabinet work. In buhl-work the patterns generally consist of continuous lines, as in the honeysuckle ornament. Two pieces of veneer of equal size, such as ebony and holly, are scraped evenly on both sides, and glued together, with a piece of paper between. Another piece of paper is also glued outside one of the veneers, and on this the pattern is drawn. A small hole is then made for the introduction of the saw, a spot being chosen where the puncture will not be noticed.

The saws used in buhl-work are of peculiar construction, and of different sizes. The frames are of wood or metal; three pieces of wood halved and glued together constitute the three sides of a rectangle; two pieces are then glued upon each side, each at an angle of 45° across the corners; the whole when thoroughly dry is then cut round to the desired curve. Screws for giving tension to the blade are commonly added, but seldom used, as the frame is only sprung together at the moment of fixing the saw, and by its reaction stiffens the blade. A handle is attached to the saw-frame at the bottom. In the piercing saw of metal the height from the blade to the frame is usually eight inches, and in the ordinary buhl-saw of wood from twelve to twenty inches, to avoid the angles of large work.

The buhl-cutter sits astride a horse or long narrow stool; the work, held in the left hand, is placed in a vise at one extremity of the horse, having a flexible jaw under the control of the foot; the saw, which has been previously inserted into the hole in the veneers, and fixed in its frame, is grasped in the right hand, with the forefinger extended, to support and guide the frame. "The several lines of the work are now followed by short, quick strokes of the saw, the blade of which is always horizontal; but the frame and work are rapidly twisted about at all angles, to place the saw in the direction of the several lines. Considerable art is required in designing and sawing these ornaments, so that the saw may continue to ramble uninterruptedly through the pattern, while the position of the work is as constantly shifted about in the vise, with that which appears to be a strange and perplexing restlessness. When the sawing is completed, the several parts are laid flat on a table, and any removed pieces are replaced. The entire work is then pressed down with the hand, the holly is stripped off in one layer with a painter's palette-knife, which splits the paper, and the layer of holly is laid on the table with the paper downward, or without being inverted. The honeysuckle is now pushed out of the ebony with the end of the scriber, and any minute pieces are picked out with the moistened finger; these are all laid aside; the cavity thus produced in the ebony is now entirely filled up with the honeysuckle of holly, and a piece of paper smeared with thick glue is then rubbed on the two to retain them in contact. They are immediately turned over, and the toothings or fine dust of

the ebony are rubbed in to fill up the interstices; a little thick glue is then applied, and rubbed in, first with the finger, and then with the pane of the hammer, after which the work is laid aside to dry." When dry it is scraped at the bottom, and is then ready to be glued on the box or furniture to be ornamented, as in ordinary veneering; it is afterward scraped and polished. An ebony honeysuckle may be inserted in a ground of holly in the same manner; and these form the *counter* or *counterpart buhl*, in which the pattern is the same, but the color reversed.

Three thicknesses of wood may be glued together, as rosewood, mahogany, and satinwood, which when cut through split asunder, and recombined would produce three pieces of buhl-work, the grounds of which would be of either kind, with the honeysuckle and centre of the two other colors respectively. These are called "works in three woods," and constitute the general limit of the thicknesses. Buhl-works of brass and wood are also sometimes made by stamping instead of sawing.

BULLET-MAKING. See CARTRIDGE-MAKING MACHINERY.

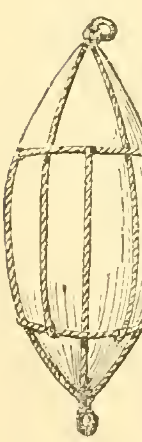
BUOY. A floating beacon serving to indicate a navigable channel, or to mark the position of sunken rocks, wrecks, sand-banks, or other obstructions to navigation. Buoys are also used as life-preservers, and it has been proposed to employ them as foundations for breakwaters and piers.

The essential requirements which a well-constructed buoy should fulfill are: 1, that it should be conspicuous in all states of the weather; 2, that it should be stable; 3, that it should be so made and moored that the most violent storms may not cause it to break adrift.

Of the ordinary forms of buoys, those most commonly used are the "nun," "can reversed," "can," "egg-bottom," "convex bottom," "flat bottom," "hollow bottom," "spherical," and "conical." The "nun" buoy, in its original form of two paraboloids joined at their bases, is represented in Fig. 588. This shape is sometimes modified to that of two cones similarly joined; or one cone is suppressed in favor of an "egg-bottom." In this case the cone which forms the superstructure is made of sheet-iron and the egg-bottom of malleable or cast-iron. In smooth water this buoy is conspicuous, and it has the further advantage of simplicity; but in a tideway or under the influence of the wind it careens over, rolls and pitches violently, and so becomes an indifferent sea-mark. In order to gain rigidity, buoys formed of a cone resting on a shallow cylinder have been used; but these, owing to their light draught of water, are not suitable for a seaway, although they have been found advantageous in rivers. Small nun buoys are commonly used to mark the location of a vessel's anchor when down. The "can" buoy is conical, frusto-conical, or conoidal in shape, and floats upon its side when moored. The buoys said to be the best for strong tideways are the can, cylindrical, and flat-bottom; for exposed channels and coasts, the English prefer the "egg-bottom."

*The English Flat-bottom Buoy* is, as are some of the others, water-ballasted; i. e., it has a cross diaphragm at a proper distance from the bottom, and the water is allowed to flow in and out of the lower compartment thus made through 8 holes an inch in diameter placed at equal distance around its sides. The water cannot be discharged unless the buoy is careened for some time, and it is therefore as completely ballasted as if the water had no means of exit. When these buoys are required for deep water, where the weight of the mooring chain is sufficient for ballast, water-ballast is not used, and the holes are plugged with hard wood. With the increased buoyancy thus obtained, the same line of flotation as in shoal water is approximately attained.

588.



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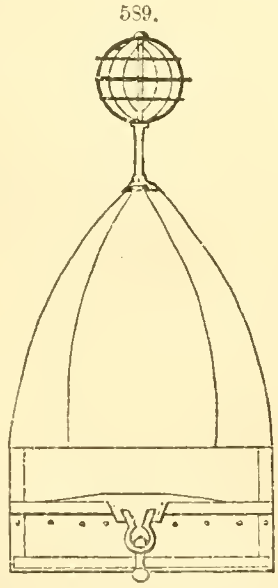

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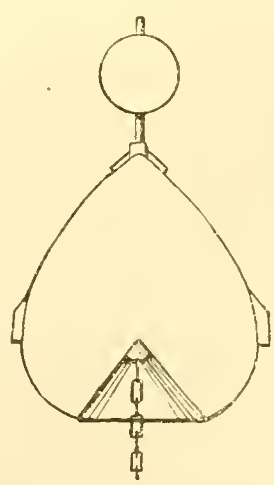

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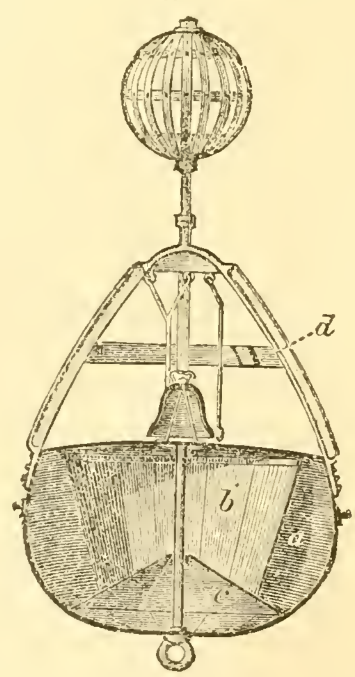


*Stoney's Keel-Buoy*, Fig. 589, is an English invention which has been found of practical value. The sides are prolonged below the bottom so as to form a circular keel, within which a large body of water is retained, so that a buoy 6 feet in diameter with a keel of 18 inches contains within the latter a body of water exceeding a ton in weight. This allows of erecting a superstructure 25 per cent. higher than other buoys of equal diameter, and affords a very large increase of stability.

*Herbert's Buoy*, represented in Fig. 590, has also been found of value. The theory of the action of this buoy is, that the air confined in the bottom forms an elastic spring upon which the buoy rebounds in gentle and easy motions, causing but moderate friction to the mooring chain, little or no pull upon the sinker, and a corresponding relief from agitation or friction to the globe and staff above.

Bells and whistles are often arranged in connection with buoys, so that the navigator is warned of the position of the latter during thick and foggy weather, when their discernment from a vessel is impossible even at moderate distances. Fig. 591 represents the bell-buoy which marks the Rundlestone off the point of Land's End, England. It is a water-ballast buoy, *a* being the outer

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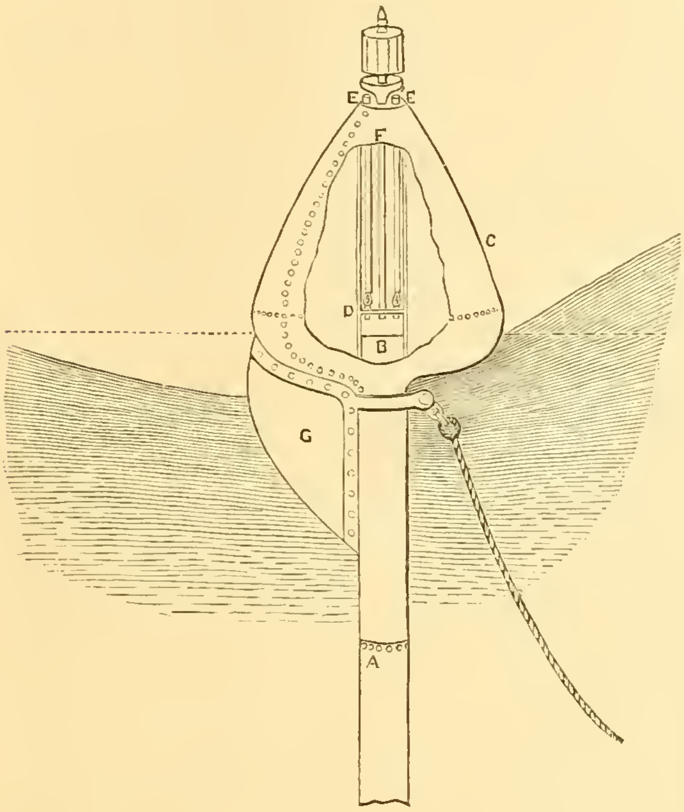


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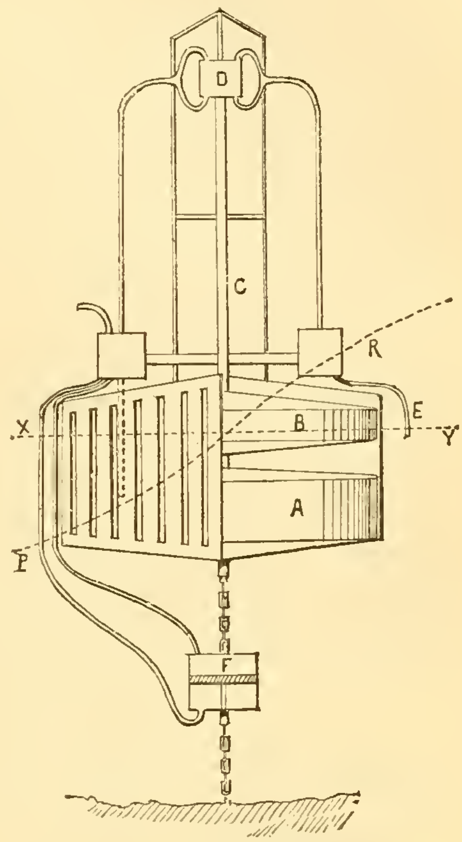


water-tight compartment, *b* the inner water-tight compartment; and at *d* are India-rubber springs. The oscillations of the buoy cause the clapper to strike against and so sound the bell.

*Courtenay's Whistling Buoy*, Fig. 592, is an exceedingly ingenious device, the efficiency of which has been well demonstrated. Its operation depends upon the fact that the agitation of water due to the existence of waves extends downward beneath the surface only to a distance equal to that measured between the trough and crest of the undulations. In other words, the agitation of the surface due to a wave 10 feet high would practically extend only to 10 feet below the level. It follows that if a long, hollow cylinder *A* is immersed to a depth exceeding in measurement the height of the waves, the water entering will not rise and fall with the varying level of the waves as they pass, but will remain at a uniform height, which will be that of the middle line between the highest and lowest point of waves, or at average sea-level, *B*, Fig. 592. Let the cylinder be attached to the lower portion of a float *C*, which rests on the surface, and hence rises and falls with each undulation. We have therefore a moving cylinder inclosing a motionless column of water, or, in other terms, a moving cylinder and a fixed piston by means of which air may be compressed in proportion to the power of the waves. It will be observed that from the diaphragm *D* extend upward two tubes *E*. These are open at the top, and are provided with valves so arranged that while air may pass down them, it cannot be forced back. The middle tube *F* has no such valve, but terminates above in a whistle. Suppose that the apparatus is carried from the position represented, in which the diaphragm *D* is just above average level, to the summit of a wave. Then the space between the constant level *B* and the diaphragm will be largely augmented, and air will be drawn in through the tubes *E*. As the buoy descends this space will be diminished, and the water-piston will compress the air and drive it out forcibly through the only outlet, which is the tube *F*. The air thus sounds the whistle. It is obvious that any modification of the water-surface will produce a similar effect. With waves 8 feet high, running at the rate of 8 per minute, that number of sounds in the same interval will be caused. With waves 20 feet high running at 4 per minute, 4 sounds would be produced. The force of the whistle blast, however, is always the same, as this depends only on the weight of the buoy and the length of the tube. Several of these buoys have been located near harbors of the United States, one of considerable power being in operation near Sandy Hook, New York.

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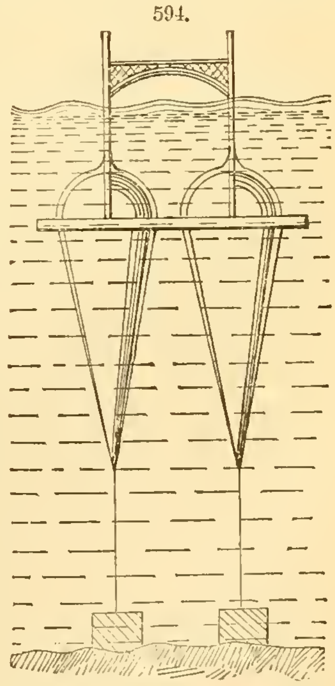

*The Pumping Buoy.*—Another utilization of wave-power through the medium of a buoy is shown in the pumping buoy represented in Fig. 593, taken from drawings exhibited in the Paris Exposition of 1878. The buoy *A* carries a double-acting pump *D* at the end of the vertical stem *C*. It is anchored to the bottom by means of a cable, which is shortened as the tide falls, elongates when the tide rises, and maintains the float *B* always in the same position with relation to the line of average level *X Y*. The aspiration-tube of the pump plunges into the water, and the emission-tube *E* (of rubber) is led to a reservoir from which a head of water sufficient to drive a water-wheel is obtained. The movement of the pump-piston is caused by the elevation and lowering of the float *B*, according as the wave rises or falls. The buoy *A* always draws on the cable. It rises at high tide, when the water from the reservoir is admitted by valves controlled by clockwork above the piston *F*, and falls at low tide, when the water is admitted below the piston.

*Buoy Foundations.*—Mr. Thomas Morris, of London, has suggested the anchoring of buoys in water beyond the depth of the deepest wave, and using them as foundations upon which to rear structures supported by uprights which shall expose but small sectional area to the action of the waves. Fig. 594 shows two of these buoys as applied to support a pier or jetty, where the upright posts, horizontal bearers, platform, and parapet, being well connected and braced, would, it is claimed, give firmness and the requisite rigidity. A similar arrangement has been proposed as a support for breakwaters (which see).

*Buoy Moorings* are usually single chains measuring in length three times the depth of the water, and mushroom anchors or screw-piles, which last are easily driven into the sand.

*Buoy Marks.*—Buoys are usually painted some distinctly visible color, or are checkered or striped so as to be easily recognized. The object of this is to enable the navigator to determine whether the buoy is to be avoided or approached, and to know on which side of it to conduct his vessel in entering a channel. Spar-buoys, consisting simply of spars of proper length, painted some particular color, are employed to mark channels in rivers and less exposed situations. Each maritime nation has its own system of marking and placing buoys, for the details of which the reader is referred to the "Sailor's Pocket-Book," Captain Bedford, R. N., Portsmouth, 1877. See also "European Lighthouse Systems," Major Elliot, U. S. A., New York, 1875; and for the use of buoys on vessels, the respective works on "Seamanship" of Captain Luce, U. S. N., and Captains Nares and Alston, R. N.

BUSH. A hollow cylinder of metal in which a shaft or other rotating piece turns, and for which its inner surface forms the bearing. The bush is generally fixed in the frame of the machine, and is made in one piece. Its object is to supply a suitable material for the bearing, which can be easily replaced when worn away. A common form of bush is shown in Fig. 595. *B* is the bush surrounding the rod *A*. Another form of bush which is largely employed is one having a collar on one end, which may be used for fixing it by means of screws to the frame. This is a better form for some purposes, as when the shaft has a collar upon it, in which case the collar of the bush forms a suitable end or side bearing for it; or if, instead of a collar, there is the boss of a wheel or pulley bearing against the bush, the collar of the latter, which can be easily repaired, is worn, and not the machine. Where there is considerable wear, it is not advisable to use bushes unless they can be turned round, as they become abraded, or can be readily replaced. The better plan is to use movable brasses which admit of adjustment to compensate for wear.

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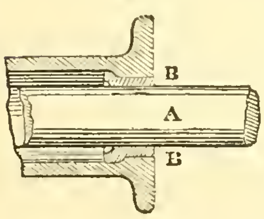



BUTTER, ARTIFICIAL. For a number of years past efforts have been made to manufacture butter from substances other than cream; but until Hippolyte Mége, of Paris, France, made known his process, all other attempts proved failures. Although Mége did not discover the exact formula by which butter is artificially manufactured, he discovered the two principal operations in its manufacture, which were afterward elaborated and perfected by Dr. H. A. Mott, Jr.

The following is the "true process for making artificial butter," as perfected by Dr. Mott:

The first matter to be attended to when a good product is to be manufactured is cleanliness. This is a most important point, to which the strictest attention must be paid.

The fat, on arriving at the factory, is first weighed, and then thrown piece by piece into large tanks containing tepid water, care being taken to place all pieces covered with blood in a separate tank to be washed. The fat in the tanks should now be covered entirely with tepid water, and left at rest for about one hour, when the tepid water should be removed and the fat thoroughly washed with cold water, then covered with fresh cold water and allowed to rest for one hour longer; the water is then again removed, and the fat thoroughly washed, for the last time, with fresh cold water, when it is ready for the next operation. The disintegrating process consists in comminuting the fat by passing it through a "meat-hasher." To do this, the fat in the tank is removed by means of a wooden car to the side of the hasher, where it is cut with a knife into pieces about five or six inches square. Piece by piece it is introduced into the hasher, which, by means of the revolving knives within, cuts the fat very fine and forces it through a fine sieve at the opposite end, and finally out of the machine and into a tub. Care must be taken not to introduce the fat into the hasher too rapidly, as the sieve or knife is apt to snap; for it requires considerable power for the disintegration, which is, of course, accomplished by steam-power.

The fat, now in a disintegrated state, is removed to the melting-tank, care being taken not to introduce into the tank any of the water which is forced out of the fat during the disintegrating process. The fat is then heated by means of the water surrounding the tank, until the temperature reaches 116° F., when the steam which heats the water is turned off. The water surrounding the tank, being much warmer than the melted fat, increases the temperature of the fat to about 122° to 124° F., when the fat completely melts. During the whole operation, from the time the steam is turned on until the melted fat is allowed to rest, the fat must be continually stirred, so that an even

temperature may be maintained. The adipose membrane of the fat, called "scrap," separates and settles to the bottom, on leaving the melted fat at rest; and a clear yellow oil floats on top, covered by a film of white emulsion of oil with the water contained in the fat.

When the scrap has completely settled, the thin layer of emulsion is skimmed off, and the clean yellow oil is drawn and received in wooden cars, which, when filled to within one inch of the top, are removed to some place to allow the oil to granulate. Care must be taken in drawing off the last portion of the oil not to allow any of the scrap to mix again with it. It is better to receive the last portion of the oil and scrap in a small galvanized iron can, and allow it to cool by itself; and when cool to melt it over again by placing the can in one of the wash-tubs and surrounding it with water heated to about 125° F., and thus separate from the scrap all the oil that is possible.

It sometimes occurs that the scrap refuses to settle, and rises to the surface, forming a layer on top of the clear oil. If such be the case, the melted fat and scrap must be stirred up together for at least ten or fifteen minutes, and then allowed to settle by standing, which it will generally do. If it does not, then it should be again stirred and allowed to stand; and if another failure follows, a quart or two of salt must be thrown on the scrap and the mixture stirred, when the scrap will soon settle to the bottom after standing.

An acid solution of the active principle of the stomach of a calf was used for some time, as proposed by Mége, in the melting process. It was thought to coagulate the "scrap" and cause it to settle more rapidly. Experiments have shown it to be unnecessary, however. The melting process, when conducted with success, occupies about two or three hours. The oil in the cars will require at least 24 or 36 hours or more to granulate, and the temperature of the room should be about 80° F. This is a very important operation, and must not be hurried, otherwise the stearine in the fat will not have time to crystallize.

The car containing the solidified oil from the melting process is removed to the press-room, which is kept at a temperature between 80° and 90° F.

The refined fat must not be so solid that it cannot be worked with the fingers with ease; if it is, it must be left in the press-room until it softens. When in the right condition, it is packed in cloths, and set in moulds to form packages about 4 inches wide, 8 inches long, and 1½ inch thick. These packages are then placed on galvanized iron plates in the press, at equal distances apart. The plates are piled one above the other until the press is entirely filled, when the packages are subjected to a slight pressure, which must be increased very gradually, and only after the oil pressed out begins to flow very slowly. The oil is received in a tin vessel, which, when filled, is replaced by another. The pressing is continued until no more oil can be obtained at the temperature of the room. The pressure is then removed and the plates unpacked, when cakes of pure white stearine are obtained, having the dimensions of about 8 inches × 5 inches × ½ inch. The stearine, after the removal of the cloths, is ready for sale. The cloths are put into one of the tanks containing hot water, until all the oil and stearine are melted off, when they are washed in another tank, and then hung up to dry. The oil and stearine in the first tank are solidified by means of cold water, collected, and sold as soap-grease.

The oil obtained from the press is removed to some cool place, until it assumes a temperature of about 70° F., when it is ready for churning.

One hundred pounds of oil are introduced into the churn at a time, with from 15 to 20 lbs. of sour milk. About 2½ or 3 ounces of solution of annotto, to which has been added from one-half to three-quarters of an ounce of bicarbonate of soda, may now be added, and the whole agitated for about 10 or 15 minutes, until milk, coloring matter, and oil are thoroughly mixed together, when the whole mixture is withdrawn from the churn, through a hole at one end, and allowed to fall into a tub containing pounded ice. As the oil flows on the ice, it must be kept in constant motion until the tub is filled with solidified oil, when another tub is put in its place. Crystallization is by this simple process completely prevented. The solidified oil, which has a slight orange* color, is left about 2 or 3 hours in contact with the ice in the tub, when it is dumped on an inclined table, where it is crumbled up so that the ice may melt and leave the solidified oil, which is then crumbled up fine by hand, and about 30 lbs. of it at a time are introduced into a churn, with about 20 to 25 lbs. of churned sour milk, and the whole agitated for about 15 minutes, when the solidified oil takes up a certain percentage of the milk, as also the flavor and odor (which were by the ice washed out from the first churning), and pure butter is produced. This is now removed from the churn to the working table, where, after standing and draining for a time, it is salted, to the extent of three-quarters to one ounce of salt to the pound of butter.

After proper working and standing for a sufficient length of time, it is packed into firkins, and is ready for sale. When thus prepared, the keeping qualities of the oil are claimed to be far superior to those of butter made by churning milk or cream. The percentage of butyrine, caprine, caproine, etc., it contains is very small (being derived from the milk in the last churning process), not sufficient to make the butter become rancid when decomposed, but quite sufficient to give the butter the so-much-prized flavor and color.

When artificial butter is made according to the process described above, exercising considerable care, the product is equal to the average butter sold in the market; it is not "Philadelphia butter," but is equal to the average samples sold at grocers' stores. Of course a poor product can be manufactured if sufficient care is not taken, as well as poor butter can be made from cream; but generally the artificial preparation is the more healthful of the two. Its keeping qualities are also superior to those of cream butter, and very greatly so to those of artificial butters made under other processes than that here described.

* The color is made purposely a slight orange, so that in the last churning process just sufficient color is destroyed to leave the product with the proper hue.

The following analyses by Drs. Brown and Mott will show how the artificial product compares with the natural one:

*Analyses of Butter.*

| CONSTITUENTS. | I. Artificial Butter. By Dr. Brown. | II. Artificial Butter. Average of two analyses. By Mott. | III. Butter made from Cream. By Mott. | Same as III. Calculated to 5.225 per cent. of Salt. |
|---|---|---|---|---|
| Water | 11.25 | 12.005 | 12.29 | 11.827 |
| Butter—solids | 88.75 | 87.995 | 87.71 | 88.173 |
| | 100.00 | 100.000 | 100.00 | 100.000 |
| Fats—oleine, palmitine, stearine, butyrine, etc. | 87.15 | 82.025 | 86.01 | 82.765 |
| Caseine | .57 | .745 | .19 | .183 |
| Salt | 1.03 | 5.225 | 1.51 | 5.225 |
| Coloring matter | Trace. | Trace. | .... | ..... |
| | 88.75 | 87.995 | 87.71 | 88.173 |

It will be seen, by comparing the first three analyses in the above table, that the difference in the percentage of fat in Mott's analyses and either of the others is owing to a greater percentage of salt (this is easily seen by comparing No. III. with the last analysis), which element may be reduced or augmented in the manufacture to suit the taste and requirements. The amount of caseine is also a trifle higher in this particular sample of the artificial than in the natural product, but not greater than the average amount usually present. H. A. M.

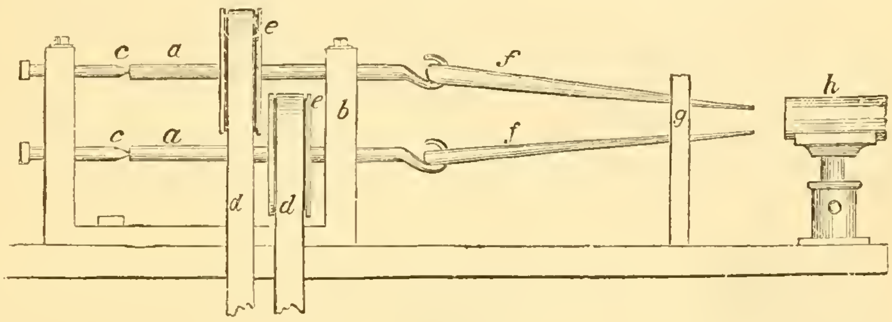
BUTTER-WORKER. See Dairy Apparatus.

BUTTON-MAKING MACHINERY. Buttons may be divided into two general classes—those with shanks, or loops of metal, for the purpose of attaching them to garments, and those without shanks; and each class is manufactured from a great variety of materials, and by a variety of methods. Of buttons with shanks, the greater number are composed of metal, although glass and mother-of-pearl are also employed. Metal buttons are formed in two ways, the blanks or bases of the buttons being either cast in a mould or stamped out of a sheet of metal; the former method is generally employed for making white metal buttons, and the latter for plated and gilt buttons. To cast buttons, a great number of impressions of the pattern of the button are taken in sand, and in the centre of each impression is inserted a shank, the ends of which project a little above the surface of the sand, and fused metal is poured over the mould. When cool, the buttons are taken from the moulds, and, after being cleansed from sand by brushing, are placed in lathes; the edges are turned, the face and back smoothed, and the projecting part of the shank also turned. The buttons are then polished by rubbing the faces upon a board spread with rottenstone of different degrees of fineness, and afterward by being held against a revolving board covered with leather, upon which is spread a very fine powder of the same material; finally, they are arranged on a sieve or grating of wire, and immersed in a boiling solution of granulated tin and cream of tartar, by which means their surfaces become covered with a thin layer or wash of the metal, which improves their whiteness without injuring their polish. The blanks of plated buttons are cut by a fly-press out of copperplate, coated on one side with silver. They are then annealed in a furnace, and afterward stamped by the descent of a weight, as in a pile-driving machine, the die being fixed in the lower surface of the weight. The soldering of the shank is performed on each button separately, by the flame of a lamp and a blowpipe. The edges of plain buttons are next filed smooth in a lathe, and the buttons are afterward boiled in a solution of cream of tartar and silver; they are then placed in a lathe, and the backs brushed, and afterward burnished with blood-stone. The metal used for gilt buttons is an alloy of copper and zinc. This metal is rolled out into sheets, and the blanks stamped out, which are then planished, if intended for plain buttons; but if for figured buttons, the impression is now given. The shanks are next attached, which is effected as follows: Each blank is furnished with a pair of small spring tweezers, which hold the shank down upon it in the proper place, and a small quantity of solder and resin is applied to each. They are then exposed upon an iron plate to a heat sufficient to melt the solder, by which the shank becomes fixed to the button; and while still warm they are plunged into nitric acid, to remove the oxide formed on the surface by the heat employed in soldering the shanks. They are then placed in a lathe, the edges rounded, and the surfaces rough-burnished, which renders them ready for gilding. Five grains of gold are fixed by act of parliament, in England, as the least quantity to be employed in gilding a gross of buttons of one inch in diameter. An amalgam is formed of gold and mercury, and the buttons are placed in an earthen vessel along with the amalgam, together with as much aquafortis as will moisten the whole, and the mixture is stirred with a brush until the buttons are completely whitened. To dissipate the quicksilver, the buttons are shaken in an iron pan, placed over a fire until the quicksilver begins to melt, when they are thrown into a felt cap, and stirred with a brush, to spread the amalgam equally over their surfaces; after which they are returned to the pan, and the mercury volatilized completely by the increased heat, leaving the gold evenly spread in a thin film over the surface of the buttons; they are then burnished in a lathe, which completes the operation. The better sort of buttons undergo the gilding process twice or thrice, and are distinguished accordingly as "double" or "treble gilt." Glass buttons are formed of glass compressed, while in the fluid state, in moulds, in which the shank is inserted; and when the glass becomes cold, the shank is firmly retained in its place. In mother-of-pearl buttons the method of inserting the shank is extremely ingenious: a hole is drilled at the back, and undercut—that is, larger at the bottom than at top; and the shank being driven in by a steady stroke, its extremity expands; on striking against the bottom of the hole, it becomes firmly riveted into the button, forming a kind of dovetail joint.

Button shanks are made by hand from brass or iron wire, bent and cut in the following manner: The wire is lapped spirally round a piece of steel bar. The steel is turned round by screwing it into the end of the spindle of a lathe, and the wire by this means lapped close round it till it is covered. The coil of wire thus formed is slipped off, and a wire fork or staple with parallel legs put into it. It is now laid upon an anvil, and by a punch the coil of wire is struck down between the two prongs of the fork, so as to form a figure 8, a little open in the middle. The punch has an edge which marks the middle of the 8, and the coil is cut open by a pair of shears along this mark, dividing each turn of the coil into two perfect button shanks or eyes.

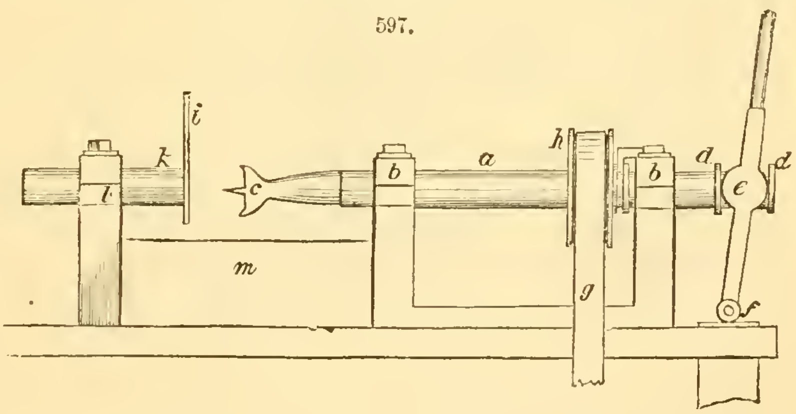
Buttons without shanks are of two kinds. The first are simply disks of horn, bone, wood, or other material, with four holes drilled through the face, for the purpose of sewing them to the garment. Horn buttons of this description are made from cow-hoofs by pressing them into heated moulds. The hoofs, having been boiled in water until they are soft, are first cut into plates of requisite thickness, and then into squares of the size of the diameter of the button, and afterward reduced to an octagonal form by cutting off the corners. They are then dyed black by immersing them in a caldron of logwood and copperas mixed. A quantity of moulds somewhat resembling bullet-moulds, and each furnished with a number of steel dies, are then heated a little above the point of boiling water, and one of the octagonal pieces of horn is placed between each pair of dies, and the mould being shut is compressed in a small screw-press, and in a few minutes the horn, becoming softened by the heat, receives the impression of the die; then the edges are clipped off by shears, and rounded in a lathe.

596.



The holes in buttons of this description are drilled by means of a lathe represented in Fig. 596. Four spindles, of which two only, *a a*, can be seen, supported in bearings at *b*, and by the centre points *c c*, are made to revolve with great velocity by means of two bands *d d* passing over pulleys *e e* fixed upon each of the spindles, each band driving two spindles, and receiving motion from a wheel worked by a treadle. At the end of each of the spindles *a a* is a hook uniting them to four other spindles *f f* by similar hooks at one end, the other end of the spindles passing through four small holes in the plate *g*, and the projecting points being formed into small drills. The button is placed in a concave rest *h*, and pushed forward against the drills by a piece of wood. The standard *g* can be exchanged for another with holes more or less apart, and the rest *h* can be set at any height to suit different-sized buttons. As the spindle-holes in the plate *g* are nearer together than the holes in the standard *b*, the spindles *f f* converge; the hooks in the spindles are therefore necessary to form a universal joint.

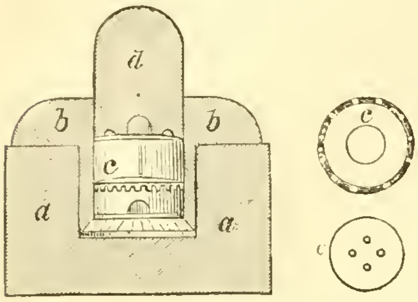
597.



The second description of buttons without shanks consists of thin disks of wood or bone, called moulds, covered with silk, cloth, or other similar material. The bone for the moulds is prepared from refuse chips sawed into thin flakes, and brought into a circular form by two operations, illustrated by Fig. 597. On one end of the spindle *a*, which revolves in bearings at *b b*, is screwed a tool *c*, and on the other are two collars *d d*, between which a forked lever *e* embraces the shaft, the fulcrum of which is at *f*. The spindle *a* is put in rapid motion by a band *g* passing over the pulley *h*, and over a band-wheel worked by a treadle; and the workman, holding the material *i* for the mould in his right hand, against a piece of wood *k* firmly held down in the iron standard *l* by two screws, by means of the lever held in his left hand, advances the tool *c* against the material *i* of the mould; the central pin of the tool drills a hole through the centre of the intended mould, while the other two points describe a deep circle cutting half through the thickness of the material, and the flat surface is cut smooth by the intermediate parts of the tool. The tool is then drawn back a little by the lever *e*, and the material shifted to bring a fresh portion of the surface opposite the tool; and when as many moulds as the plate of the material will afford are thus half cut through, the other side is presented to the tool, and, the central point of it being inserted in the hole made in the first part of the operation, the other two teeth cut another deep circle exactly opposite the former one through the remaining substance of the material, and the mould is left sticking on the tool. By drawing back the lever *e* the tool recedes, and the mould, meeting a fixed iron plate, is pushed off the tool, and falls into a small box *m*.

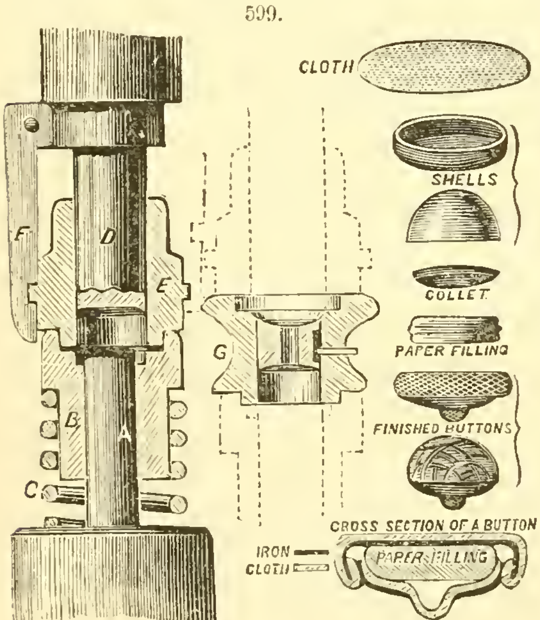
Covered buttons having come into very general use, various improvements have been introduced in the manufacture of them, and patents for this purpose have been granted to various parties. The following is Mr. Sanders's method of making covered buttons: A piece of the material with which the mould is to be covered is cut of a circular shape, somewhat larger than the intended button; upon this is placed a disk of card of the exact size of the button, and next a disk of paper coated with an adhesive composition, which will become soft and sticky by heat; and upon these is laid a button-mould *e*, having four holes, through which threads or strings have been passed to form the flexible shank. These circular disks, being put together, are then laid over a cylindrical hole in a metal block *a a*, Fig. 598; this hole being exactly the size of the intended button, and the covering of the button being larger than the hole, when the disks are pushed down into the hole, the material of the covering will wrinkle up on the edges round the other disks. The tube *b b* is then introduced into the cylindrical hole, and its lower edge, being beveled inward, will, as it is pressed down, gather the plaits of the cloth on the edge of the button; toward the centre is a metal ring or collar, *c*, having teeth round its edge, somewhat like a crown-saw, which is now passed down the tube *b*, and driven with considerable force by the punch *d*; and the block *a a* having been previously heated, the adhesive matter will be softened, and cause the several disks to stick together, which, when taken out and become cold, will be very firm and retain its shape.

598.




The following is the common process of making covered buttons: Thin sheets of metal, known as "tagger's iron" (thickness No. 36 to No. 38, and quality according to the more or less fine grade of button to be made), are carried by hand rapidly under a descending punch. This punch is double, the outer portion cutting out a circular blank of the proper size, while an inner punch descends and forces the blank into a die, so that its periphery is turned upward, or so that the entire blank is rendered hemispherical in shape. These two forms of shells are shown in Fig. 599. One machine, driven by steam-power, will easily form 50 gross of shells per hour.

599.




The shells are next annealed in an ordinary furnace, and then are conveyed to a horizontal revolving barrel, where they are tumbled with sawdust until they are thoroughly cleaned from all dust and grease. The other part of the skeleton of the button is known as the collet. Inasmuch as the under side of this is exposed, one face of the iron plate is japanned. The piece, by a somewhat similar arrangement of punches to that already described, is first cut out in the form of a circle, and then its inner part is punched out, leaving it in annular shape. There are still three more portions, namely: the cloth cover; the canvas tuft-piece, which rests above the collet, and a portion of which protrudes through the central opening in the latter, to furnish a tuft by which the button is sewed on the garment; and the inner filling. The last is made of specially prepared pasteboard, and in common with the other portions mentioned is simply punched into shape.

The grouping together of these various parts is effected in two operations. By the first, the collet and tuft-piece are fastened. The tuft-piece is laid in the collet under a press, which, descending, forces the fabric, as already stated, through the aperture in the metal, producing the nipple of cloth in the rear. The paper filling is then inserted, and the button is then ready for the final assembling. The machine for this purpose is represented in Fig. 599. *A* is a fixed mandrel. *B* is a sleeve thereon, supported by a spring, *C*. On the upper mandrel, *D*, is another sleeve, *E*, which is sustained by the catch *F*. The lower face of the mandrel *D* is hollowed, and a projecting annular portion of the upper sleeve enters a corresponding portion of the lower one, *B*. In using the machine, a shell is placed over the lower mandrel, and above it is laid the covering fabric. The operator then causes the upper mandrel to descend. The cloth is thus pressed down around the shell, and on the return upward movement both cloth and shell are carried up inside the sleeve *E*. The operator now inserts the annular piece *G*, in which there is a suitable cavity to receive the combined collet, tuft-piece, and filler, the last being uppermost. The upper mandrel is again brought down, and the shell is thus forced upon the collet, filler, etc., the cloth cover being at the same time turned under. Reference to the section of the finished button will make this clear. Nothing further remains but to attach the buttons by dozens to cards, or make them up for the market in any desired attractive way.

CAAM. The weaver's reed. Setting the reed by arranging the warp-threads is termed "caaming."

CAISSON. See FOUNDATIONS.

CALCINATION. The chemical process of subjecting metallic bodies to heat with access of air, whereby they are converted into a pulverulent matter, somewhat like lime in appearance. The term *calcined* is, however, now applied to any substance which has been exposed to a roasting heat.

CALCULATING MACHINES. Machines of this kind are designed to produce arithmetical and other tables which shall be rigorously correct. In navigation and the higher branches of astronomy the use of tables is very great, and, being constructed by human heads and hands, they all contain errors of greater or less magnitude. The principle upon which these machines are constructed may be described as follows: In the manner in which quantities are combined in the common system of numeration, the value of each figure is ten times greater than it would be if it occupied a position one place to the right. Thus, in the number 1879, although 9 is greater than 7, yet the 7 in this position represents a larger sum than the 9, because it occupies a place to the left of the 9. The quantities really expressed by the figures 1879 are 1,000, 800, 70, 9; but in practice we omit the ciphers, and place the significant figures side by side, preserving their proper position from the right hand. If a wheel be constructed on whose axis is a pinion with leaves or teeth, if these teeth work into another set of teeth or cogs on the periphery of another wheel, and if the teeth on the latter wheel are just ten times as numerous as those on the pinion, this system being made to revolve, the pinioned wheel will revolve just ten times as fast as the other. This produces a kind of analogy between the decimal notation and the working of the wheels; for it takes 10 units to make up one figure or unit in the second place in common numeration, and it requires 10 revolutions of the pinioned wheel to impart one revolution to the larger wheel. This is the fundamental principle in calculating machines. In such machines there are a number of dial-faces, each marked with figures from 1 to 10; these dial-faces are fixed upon wheels, the teeth of which work into the pinions of other wheels, on which are similarly divided faces or disks, so that, while one face indicates units, another indicates tens, a third hundreds, and so on. These wheels and dial-faces may be differently arranged in different machines, but the principie is the same in all.

A calculating machine, called the difference engine, was constructed by Mr. Babbage for the English government at an expense of £20,000, to be used in preparing logarithmical and trigonometrical tables. A valuable feature introduced into this machine is the power of printing the tables as fast as it calculates them. Another machine, called the analytical engine, was invented by the same gentleman, of greater power than the first. This contains a hundred variables, or numbers susceptible of changing, and each of these numbers may consist of twenty-five figures. The distinctive characteristic of this machine is the introduction into it of the principle which Jacquard devised for regulating, by means of punched cards, the complicated patterns of brocaded stuff.

The machine in the Dudley Observatory, Albany, was invented by G. and E. Scheutz, of Stockholm, Sweden, who sought to attain the same ends that Mr. Babbage had attained, but with simpler means. Their engine proceeds by the method of differences, calculating to the 15th place of decimals, and stamping the eight left-hand places in lead, so as to make a stereotype mould, from which plates can be taken by either a stereotype or electrotype process, ready for the printing-press. It can express numbers either decimally or sexagesimally, and prints by the side of the table the corresponding series of numbers or arguments for which the table is calculated.

600.

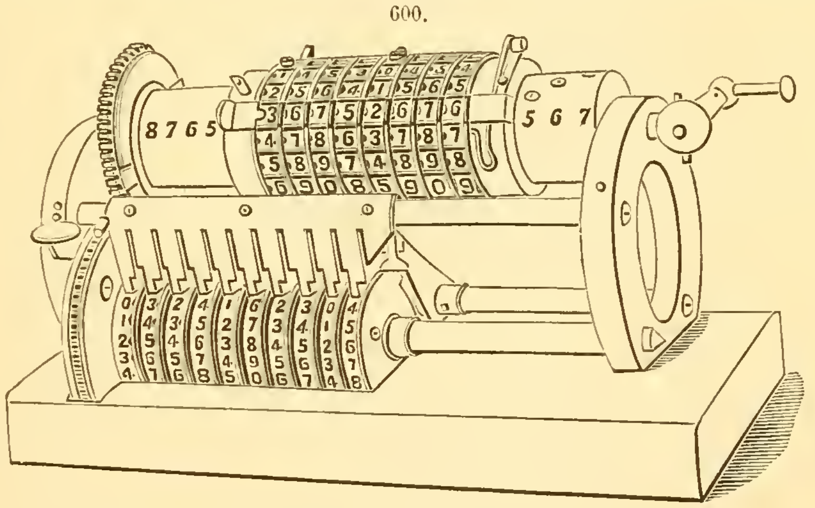



Fig. 600 represents a simple form of calculating machine devised by Mr. George B. Grant. There is an upper cylinder, which is turned by the crank, and which itself drives a smaller shaft underneath. A slide, that can be set in eight different positions on the cylinder, carries eight figured rings that can be set to represent eight or any smaller number of decimal places. Each turn of the crank adds the number set up on the rings to the number represented on the ten recording wheels carried by the lower shaft. The multiplication process will best be understood by an example. To multiply 347 by 492, the three upper rings are set at 3, 4, and 7, respectively. The cylinder is then turned twice to multiply by the units figure of the multiplier. If now the slide is carried along one notch, where each ring will act on the next higher recording wheel, and turned 9 times, 347 will be multiplied by 90, and the product at the same time will be added to the product already scored. Another shift of the slide and four turns will complete the operation, and show the result, $170724 = (347 \times 2) + (347 \times 90) + (347 \times 400)$, upon the recording wheels. A half-turn of the crank backward erases this result, bringing all the wheels to 0, ready for the next operation.

Division is the reverse of multiplication. The dividend is set up on the wheels, the divisor on the rings, and the quotient records itself on the upper recording wheels. The machine of the size illustrated will use numbers of eight or less figures, and show the result in full, if not over ten figures, and its upper figures if more than ten places are necessary.

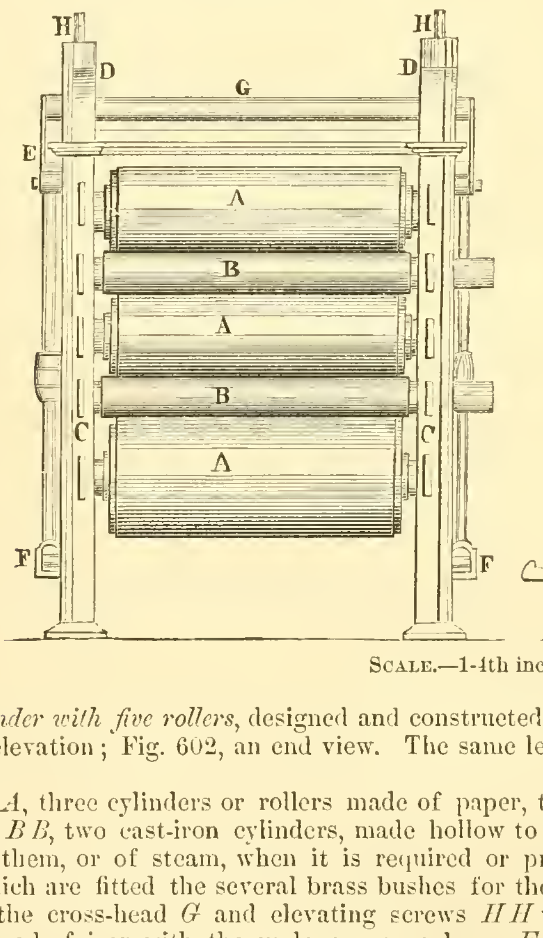
CALENDER. A machine to give a smooth, hard surface to paper, or to cotton and linen fabrics. Calendering is the finishing process by which the goods are passed between cylinders or rollers, and made of a level uniform surface. The machine consists of a number of rollers contained in a massive framework; the rollers are connected with a long lever loaded with weights at the further extremity, by which or by means of screws almost any amount of force may be applied, and the surface texture

of the cloth varied at pleasure. With considerable pressure between smooth rollers, a soft, silky lustre is given by equal flattening of the threads. By passing two folds at the same time between the rollers, the threads of one make an impression on the other, and give a wiry appearance, with hollows between the threads. The rollers are made of cast-iron, wood, paper, or calico, according to the uses for which they are designed. The iron rollers are sometimes made hollow, for the purpose of admitting either a hot roller of iron or steam when hot calendering is required. The other cylinders were formerly made of wood, but it was liable to many defects. The advantage of the paper roller consists in its being devoid of any tendency to split, crack, or warp, especially when exposed to a considerable heat from the contact and pressure of the hot iron rollers. The paper takes a fine polish, and, being of an elastic nature, presses into every pore of the cloth, and smooths its surface more effectually than any wooden cylinder, however truly turned, could possibly do.

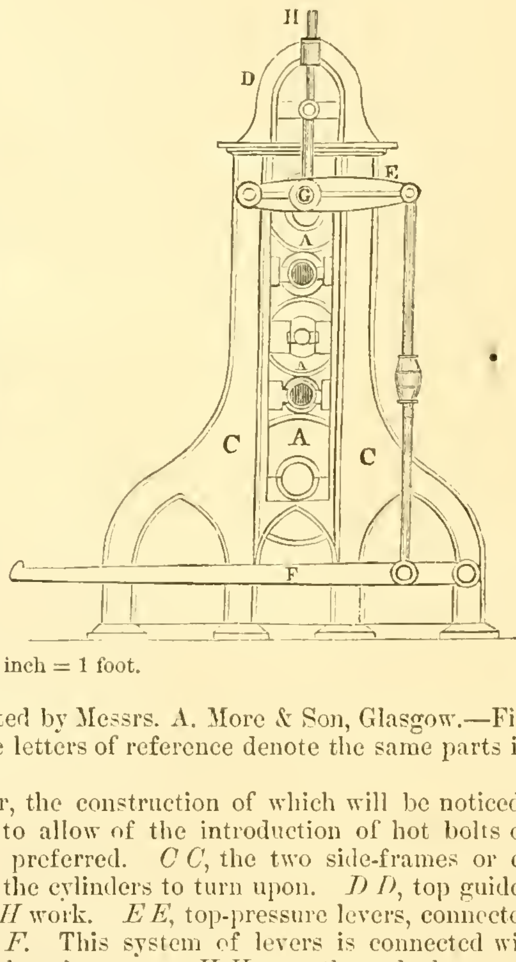
In a five-rollered machine, the cloth coming from behind, above the uppermost or 1st cylinder, passes between the 1st and 2d; proceeding behind the 2d, it again comes to the front between the 2d and 3d; between the 3d and 4th it is once more carried behind, and lastly brought in front between the 4th and 5th, where it is received and smoothly folded. At this time the cloth should be folded loosely, so that no mark may appear until it is finally folded in the precise length and form into which the piece is to be made up, which varies with the different kinds of goods, or the particular market for which the goods are designed. When the pieces have received the proper fold, they are pressed in a hydraulic press previous to being packed.

From the great weight of calendering machines, it is necessary that they should be fixed on the basement floor. After the cloth has received its final gloss from these machines, it is taken to the cloth-room to be measured preparatory to being folded and packed for sale or transportation.

601.




602.




SCALE.—1-4th inch = 1 foot.

*Calender with five rollers*, designed and constructed by Messrs. A. More & Son, Glasgow.—Fig. 601, a side elevation; Fig. 602, an end view. The same letters of reference denote the same parts in each view.

*A A A*, three cylinders or rollers made of paper, the construction of which will be noticed hereafter. *B B*, two cast-iron cylinders, made hollow to allow of the introduction of hot bolts of iron within them, or of steam, when it is required or preferred. *C C*, the two side-frames or cheeks, into which are fitted the several brass bushes for the cylinders to turn upon. *D D*, top guides, into which the cross-head *G* and elevating screws *H H* work. *E E*, top-pressure levers, connected by a strong rod of iron with the under-pressure lever *F*. This system of levers is connected with the cross-head *G* by two strong links of iron. The elevating screws *H H* pass through the cross-head and rest upon a strong cast-iron block, into which is fitted the brass bush of the top paper roller. By means of the screws, the cross-head and levers can be raised or depressed as required; and when the calender is working warm and requires to be stopped, the elevating screws are screwed up for the purpose of lifting the paper rollers off the hot cylinders, to prevent their being injured by the heat.

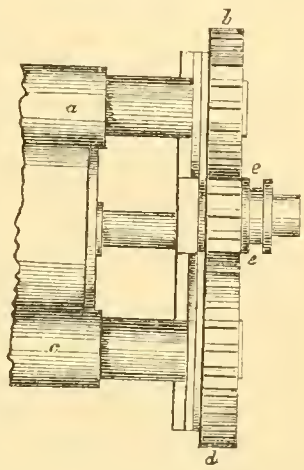
The construction of the paper rollers or cylinders is as follows: Upon each end of an arbor of malleable iron, of sufficient strength to withstand the necessary pressure without yielding, is fastened a strong plate of cast-iron, of the same diameter as the roller to be made: the plate is secured in its proper place by a ring of iron, cut in two, and let into a groove or check turned in the arbor. When the roller is finished, the annular pieces are kept in their groove by a hot hoop put upon the outside of them, and allowed to cool. A plate is fitted on the other end, of exactly the same size, and in the same manner.

In building the rollers, one of the plates is taken off the arbor, but the other is allowed to remain in its place. The paper sheets of which the rollers are to be made have each a circular hole cut in the

centre of it, of exactly the same diameter as the arbor. The sheets are then put upon the arbor, and pressed hard against the fixed plate. When the arbor is filled with paper, it is put into a strong hydraulic press, and pressed together—always adding more paper to make up the deficiency caused by the compression, until the mass can be pressed no harder. The half rings are then put in their place, to prevent the plate from being pressed back by the elasticity of the paper. The roller is now to be dried sufficiently in a stove, the heat of which causes the paper to contract so as to be quite loose. The roller is then again taken to the press, and the unfixed plate being removed, more paper is added, and the whole again compressed, until the roller is hard enough for the purpose to which it is to be applied. It is next turned truly in the lathe till it acquires a very smooth surface.

Fig. 603 shows the manner in which the calender is geared to make it a *glazing* calender. In this cut, *a* marks the top cylinder of the calender, upon which is keyed a spur-wheel *b*; and *e* is the under cylinder, upon which is also keyed a spur-wheel *d*. The intermediate or carrier-wheel *e e*, when drawn into gear, reduces the speed of the under cylinder *c* one-fourth. Now, the cylinder *a* being the one that gives motion to all the rollers, and revolving always at the same speed, the cloth in its passage through all the rollers below the cylinder *a* is carried through at a speed *one-fourth* less than if it passed only below the cylinder *a*; consequently, when it comes into contact with *a*, it is rubbed, and thereby *glazed*, in consequence of the cylinder *a* moving one-fourth quicker than the cloth, as above stated.

603.



604.

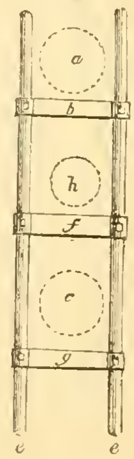
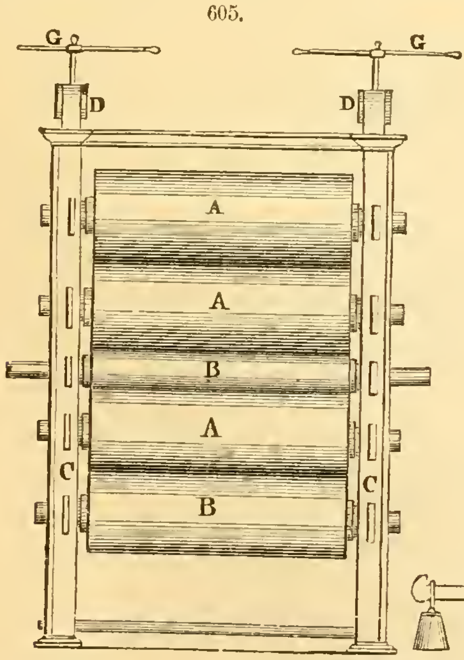


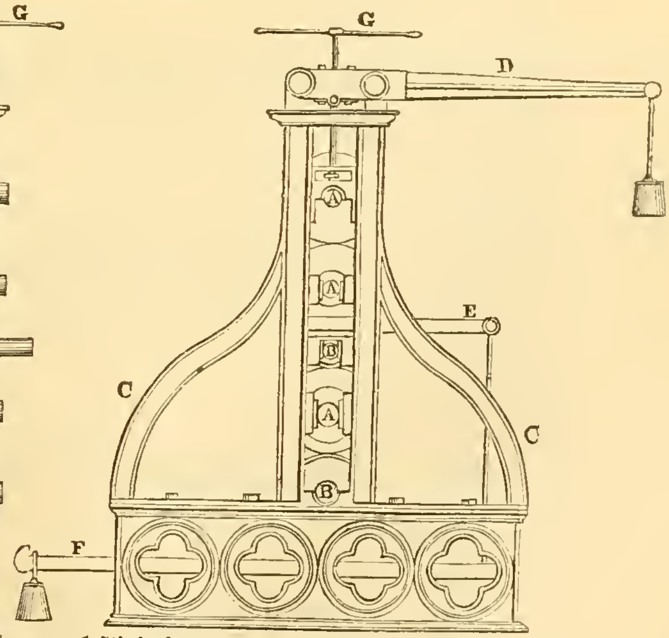
Fig. 604 shows the manner in which the rollers are lifted clear of each other when the machine is stopped. In this, *e e* are two rods of iron, attached to the block or seat of the top roller; *b f g*, three bridges of malleable iron, capable of sliding upon the rods *e e*, but held fast upon the rods when once they are adjusted to their proper places by pinching screws. The bridge *b* is placed half an inch clear of the bearing of the cylinder *a*, when all the rollers are resting upon each other; the bridge *f* is placed one inch below the bearing of the paper roller *h*; and the bridge *g* is placed one inch and a half below the bearing of the cylinder *c*. When the pressure screws of the calender are lifted, the blocks of the top roller being attached to them, the rods *e e* are lifted also, and along with them the different rollers as the bridges successively come into contact with their respective bearings.

The manner of passing the cloth through the calender varies very much, according to the amount of finish required upon it. The various methods are accomplished by different arrangements of the gearing, so that a calender calculated to do all the different kinds of finishing becomes a very complicated machine, on account of the quantity of gearing required. For common finishing, the method of passing the cloth through the calender is as follows: The cloth is passed alternately over and under a series of rails placed in front of the machine, so as to remove any creases that may be in it, and is then introduced between the lower roller *A* and cylinder *B*; returns between the lower cylinder *B* and the centre roller *A*; passes again between the central *A* and the upper *B*; and again re-

605.




606.




Scale.—1-5th inch = 1 foot.

turns between the top pair *A B*, where it is wound off on a small roller (hid in the drawings by the framing of the machine), pressing against the surface of the top roller *A*. When this small roller is filled with cloth it is removed, and its place supplied by another, to be in succession filled as the motion of the machine progresses.

*Water-Mangle, with two copper and three wooden rollers*, designed and constructed by Messrs. A. More & Son.—This machine, Figs. 605 and 606, differs nothing in principle, and little in general construction, from the five-rollered calender above described, except in this—that it is intended for wet goods. It is drawn to a scale slightly less, but the views given and the lettering of the parts correspond to those of the preceding figures.

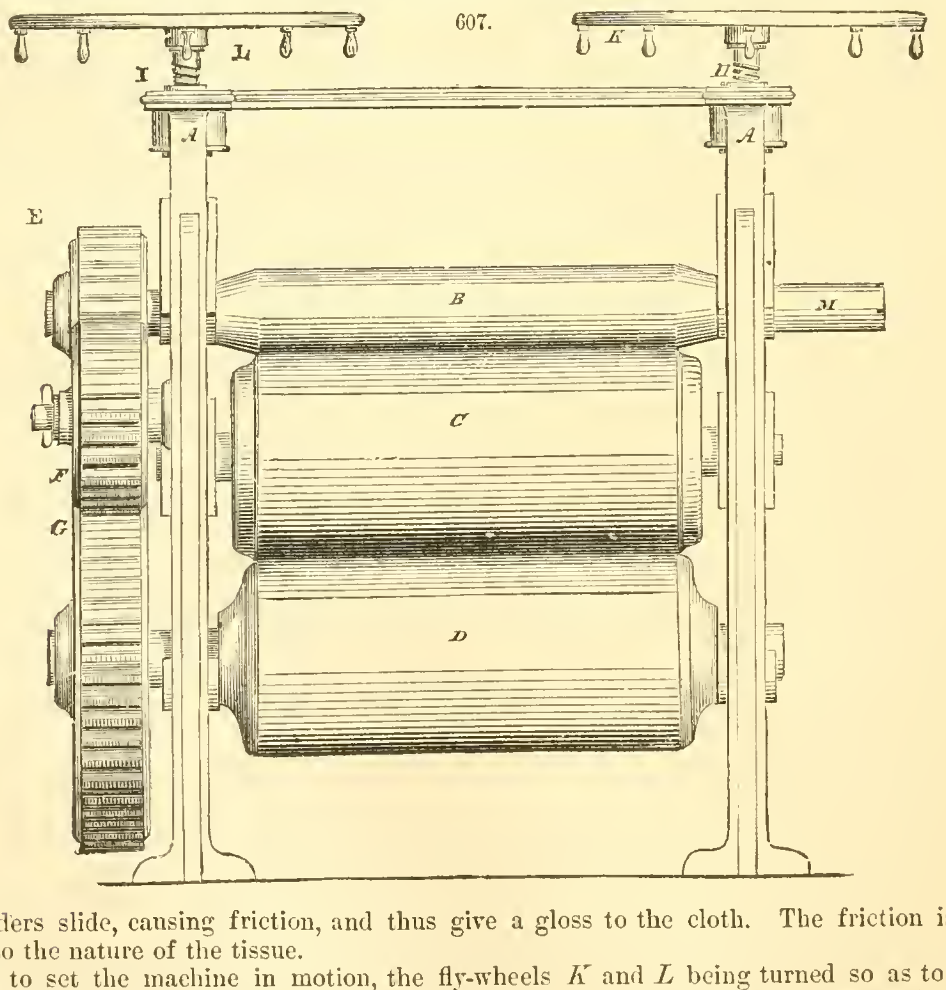
*A A A*, the three wooden rollers, and *B B*, the two copper rollers of the mangle. These last consist of a copper cover upon a cast-iron body, through which passes a wrought-iron arbor, differing from those of the wooden rollers in being round, whereas these are square between the bearings. The smaller of the two copper rollers, namely, the third in order, is in this arrangement the driver, the mangle being driven like the calender, by a system of reversing gear not shown in the drawings. The pressure in the mangle is brought on by a system of levers, which differ slightly from that described. In this, indeed, there are strictly two distinct pressures: that brought on the axis of the middle roller by the lever *E*, which is connected by a link with the weighted lever *F*; and that transmitted through the whole system of rollers by the single-weighted lever *D*. The weight of this last is regulated by means of a set-screw, which turns in a nut in the jaws of the lever *D*, and bears upon the set-block which rests upon the arbor of the top roller. This pressure is thus transmitted downward from the top roller throughout the whole set, and at the middle roller *B* is added to the pressure obtained by the lever *E*. By this arrangement, the pressure between the three under rollers is greater by the pressure of *E* than it is between the upper pair; but for very high pressure the lever *D* may be locked by set-pins and the set-screws turned down by the hand-wheel *G*, until the requisite degree of pressure is obtained. The manner of passing the cloth through this machine is the same as that already described in the calender, with this single exception, that before the cloth enters between the lowest roller *A* and the small cylinder *B*, jets of water from a pipe perforated with small holes, extending the whole width of the machine, are allowed to play upon the cloth, so as to impart to it sufficient moisture for causing it to receive the requisite degree of smoothness preparatory to the starching process, and at the same time allow the cylinder *B* to free it from any impurities that may be remaining in it, by forcing them back with the expressed water.

*Description of Calender, Figs.* 607 *and* 608.—*A*, two cast-iron frames. *B*, *C*, *D*, three cylinders. *E*, *F*, *G*, three cog-wheels. *H*, *I*, two force-screws. *K*, *L*, two fly-wheels with handles.

The cylinder *B*, which is in cast-iron, and hollow, is heated by another iron cylinder heated red-hot. The material of the cylinder *C* is pasteboard; its axle is of wrought-iron. These three cylinders must be perfectly round and parallel.

The wheel *F* forms the communication between *E* and *G*, which rest upon the cylinders *B* and *D*. The relation of *F* to the circumference of the cylinders is such that, when the machine is set to work,

607.

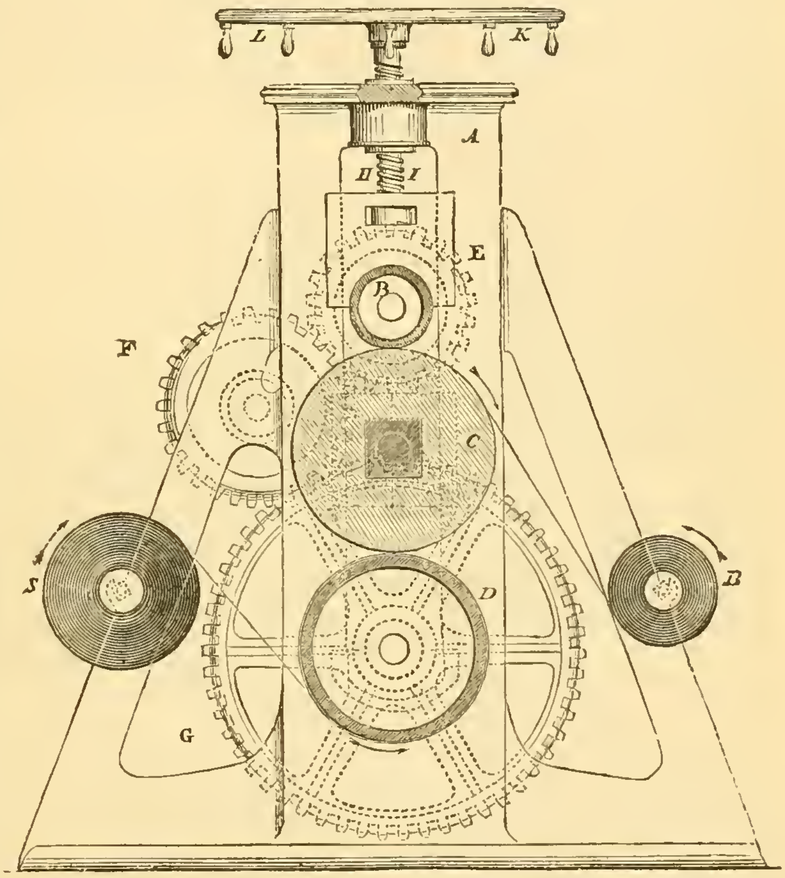



these cylinders slide, causing friction, and thus give a gloss to the cloth. The friction is variable according to the nature of the tissue.

In order to set the machine in motion, the fly-wheels *K* and *L* being turned so as to press the screws *H* and *I* against the pillows of the first cylinder *B*, the cloth is placed between the rollers in the direction indicated by the arrows.

Since the introduction of web-perfecting printing-presses, rolls for calendering paper require great truth in their roundness and parallelism. Suppose, for instance, a pair of rolls to be the 10,000th part of an inch out of parallel, and the paper rolled by them therefore the 20,000th part of an inch thicker on one side than on the other. Now, suppose a roll of such paper to be 33 inches in diameter, the mandrel upon which it is rolled being 3 inches thick, and there to be 450 thicknesses of paper to an inch; the roll would in such case be .675 of an inch in diameter or 2.12 inches in circumference greater at one end than at the other; and the effect of such a roll being placed upon a modern printing-press, through which it would require to be drawn at a speed of from 15 to 20 miles an hour, would be that the whole strain due to unwinding the paper at such a great speed would be sustained by the paper unwinding from the small diameter of the roll, causing it to tear. To remedy this defect, Messrs. J. Morton Poole & Co., of Wilmington, Delaware, have introduced a finishing process for rolls, which has achieved remarkable success, and which has been in consequence introduced in Europe. That process is as follows: After the roll has been turned as accurately as is practicable with the steel tools, it is finished in the grinding lathe or machine; and the principle upon which this lathe operates is as follows: If we suppose the lower part of a compound lathe-carriage to support the upper part so as to permit to the latter a free, swinging, cross-feed motion, and form it so as to carry two revolving corundum-wheels, one on each side of the roll, so that the horizontal centre line of the roll will be level with the centres of the corundum-wheels, it is evident that the two will form a pair of grinding calipers, and will adjust themselves to touch the roll equally on both sides, just the same as the points of a pair of calipers, held loosely, will adjust themselves to the diameter of a roll. It is also evident that a pair of wheels adjusted in this manner, if traversed along the roll, will come in contact with, and operate upon, the roll in places where the diameter of the roll is equal to or exceeds the nearest width between the two corundum-wheels, while such parts of the roll as are of a diameter less than is the said distance between the wheels will remain untouched. If, therefore, the wheels are adjusted in their distance apart and operated along the roll until all the turning-marks are effaced, the roll will be made quite parallel, except in so far as the reduction in the diameters of the grinding-wheels and the deflection or sag of the roll may prove disturbing elements.

608.




The latter element is of no practical moment, however, since its effect upon an ordinary roll 8 feet long has been computed not to affect the diameter of the roll to more than the 200,000th part of an inch. Referring to the first disturbing element, it is less in the process adopted by Messrs. Poole than in any other yet known, for the following reasons: The ordinary plan is to perform the grinding with a wheel on one side only of the roll. Now, supposing it to be practicable to move the carriage containing the wheel so delicately as to be able to put on a cut the 100th part of an inch in depth, the diameter of the roll will be reduced one-fiftieth of an inch, and the amount of the abrasion of the emery-wheel will be that due to the abrading of that quantity or weight of metal; but if the feed of one of Messrs. Poole's corundum-wheels is moved the 100th of an inch, the reduction in the size of the roll will be the 100th of an inch only; so that, with the same amount of feed, Messrs. Poole take off only one-half the amount of metal, and have twice the area of grinding-wheel to do it with. Hence the deviation from parallelism is only one-fourth as much under their process as it is under the process usually employed. From the cross-swing motion, then, of the frame carrying the corundum-wheels, the parallelism of a roll is inevitable, providing that the roll runs circumferentially true. The ordinary method of grinding a roll to run true in the lathe is to grind it up with one emery-wheel in a fixed position; and this was the plan formerly employed by Messrs. Poole, in which case the advantage obtained by their process was that, since an emery-wheel in a fixed position will grind a roll to run true, and the error arising from its use lies in the parallelism of the roll, it is necessary only to finish the roll with the two wheels in position to insure both roundness and parallelism. The only objection to this plan was that the grinding the roll true could be performed twice as quickly with the two wheels as it could be with the one, and could be proceeded with simultaneously with the truing for parallelism. The method of accomplishing this result is as follows: By

placing a slight pressure upon the frame carrying the corundum-wheels, so as to offer a slight resistance to its cross-swing, the high spots or places upon the roll will press more heavily upon the respective corundum-wheels as it passes them, and, as a consequence, will suffer the most abrasion. This remark applies, however, to high spots which do not extend entirely around the circumference of the roll, and not to high places due to an increase of diameter; or, in other words, it applies to those high spots which constitute a want of truth or roundness in the roll. If then a roll, being out of round and out of parallel, is operated upon with the wheel-frame or carriage slightly resisted, the truing for both roundness and parallelism will progress jointly; then, when the roll is ground so as to run true, the wheel-carriage is allowed to swing freely while the finishing traverses are made. J. R.

CALICO-PRINTING is the process of impressing designs in one or more colors upon cotton cloth. The coloring substances employed are divided into *substantives* and *adjectives.* The former are capable of producing permanent dyes of themselves; the latter require certain intermediate matters.

It is often necessary to apply some substances to the cloth which shall act as a bond of union between it and the coloring matter. These substances are usually metallic salts called *mordants,* which have an affinity for the tissue of the cloth as well as for the coloring matter when in a state of solution, and form with the latter an insoluble compound. The usual mordants are alum, and several salts of alumina, peroxide of iron, peroxide of tin, protoxide of tin, and oxide of chrome. Mordants are useful for all vegetable and animal coloring matters which are soluble in water, but have not a strong affinity for tissues.

To prevent the mordant or the coloring matter from spreading beyond the proper limits of the design, *thickeners* are used to bring it to the required consistence; the most useful are wheat starch and flour, but many other materials are used. The colors, with the proper thickeners, are prepared in vessels furnished with steam-jackets, for raising the contents to the required temperature.

There are eight different styles of calico-printing, each requiring different methods of manipulation, and peculiar processes:

1. The *madder style* (so called from its being chiefly practised with madder), to which the best chintzes belong, in which the mordants are applied to the white cloth with many precautions, and the colors are afterward brought up in the dye-bath. These constitute permanent prints. 2. The *padding style,* in which the whole surface of the calico is imbued with a mordant, upon which afterward different-colored figures may be raised by the topical application of other mordants joined to the action of the dye-bath. 3. The *resist style,* where the white cloth is impressed with figures in resist paste, and is afterward subjected first to a cold dye, as the indigo vat, and then to a hot dye-bath, with the effect of producing white or colored spots upon blue ground. 4. The *discharge style,* in which thickened acidulous matter, either pure or mixed with mordants, is imprinted in certain points upon the cloth, which is afterward padded with a dark-colored mordant, and then dyed, with the effect of showing bright figures on a dark ground. 5. *China blues,* a style resembling blue stone-ware, practised with indigo only. 6. The *decoloring style,* by the topical application of chlorine or chromic acid to dyed goods. This is sometimes called a discharge. 7. *Printing by steam,* a style in which a mixture of dye extracts and mordants is topically applied to calico, while the chemical reaction which fixes the colors to the fibre is produced by steam. 8. *Spirit colors,* produced by a mixture of dye extracts and a solution of tin. These colors are brilliant but fugitive.

The processes actually required for finishing a piece of cloth in the madder style, as, for example, in producing a red stripe upon a white ground, are numerous. The bleached cloth is submitted to nineteen operations, as follows: 1. Printing on mordant of red liquor (a preparation of alumina), thickened with flour, and dyeing; 2. Ageing for three days; 3. Dunging; 4. Wincing in cold water; 5. Washing at the dash-wheel; 6. Wincing in dung-substitute and size; 7. Wincing in cold water; 8. Dyeing in madder; 9. Wincing in cold water; 10. Washing at the dash-wheel; 11. Wincing in soap-water containing a salt of tin; 12. Washing at the dash-wheel; 13. Wincing in soap-water; 14. Wincing in a solution of bleaching powder; 15. Washing at the dash-wheel; 16. Drying by the hydro-extractor; 17. Folding; 18. Starching; 19. Drying by steam.

By different engraved rollers, each supplying a different mordant, various shades and colors are afterward brought out by one dye. Before the mordanted cloth is dyed, it is hung for some time in airy chambers in order that the mordants may intimately combine with the fibre. This operation, called ageing, is abbreviated by a process in which the goods are passed over rollers in a room in which a small quantity of steam is allowed to escape.

The aniline colors are largely used for calico-printing, and are applied topically, the only mordant used being albumen or vegetable gluten prepared in various ways.

The printing-cylinders are of copper, and vary in length from 30 to 40 inches, according to the width of the calico; the diameter varies from 4 to 12 inches. Each cylinder is bored through the axis, and accurately turned from a solid piece of metal. To engrave a copper cylinder by hand, with the multitude of minute figures which exist in many patterns, would be a very laborious and expensive operation; and the invention of Jacob Perkins of Massachusetts, for transferring engravings from one surface to another by means of steel roller dies, has long been applied to calico-printing with perfect success. The pattern is first drawn upon a scale of about 3 inches square, so that this size of figure, being repeated a number of times, will cover the printing-cylinder. This pattern is next engraved in intaglio upon a roller of softened steel, about 1 inch in diameter and 3 inches long, so that it will exactly occupy its surface. This small roller, which is called the *die,* is next hardened by heating it to redness in an iron case containing pounded bone-ash, and then plunging it into cold water, its surface being protected by a chalk paste. This hardened roller is put into a rotary press, and made to transfer its design to a similar roller in a soft state called the *mill;* the design which was sunk in the die now appears in relief on the mill. The mill in its turn is hardened, and,

being put into a rotary press, indents upon the large copper cylinder the whole of the intended pattern.

As the use of copper in rollers constitutes a large item of expense, there have been many inventions for rollers only partially of that metal or entirely of other substances. Iron has been used as an inner cylinder for a thin copper envelope; in one case these cylinders had corresponding grooves to prevent turning one upon the other. A seamless tube of copper has been placed upon a taper tube of sheet-iron, and tin has been employed to coat the interior of a copper shell, which is then soldered to an iron lining. Brass rollers have been tested, but the objection lies in the hardness and shortness of the alloy. Various other alloys, notably of zinc, and also German silver, have been employed, not, however, with success. Rollers, either entirely of papier-maché, or of that material covered with a half-inch tube of copper, have been tested, and numerous plans involving electric deposition of the metal have been broached. By the latter means, instead of turning off the worn face of the copper to expose a new surface, they were maintained at the original diameter by a new coating of copper at a minimum expense. One of the most practical plans for utilizing old copper rollers is that patented by Mr. T. Knowles, which dispenses with the necessity of adjusting the roller to the mandrel whenever the cylinder requires renewing. Over the old thin roller an exterior roller is forced, and when this is worn thin another new one is substituted. The exterior roller is held in due position tightly by means of a nib. The etching process is resorted to in case of injury to a roller whereby a sinking of the surface is produced, all but the sunk portion, which is covered with an acid-resisting paint, being exposed to the action of acid until the desirable flatness has been obtained. Strong aquafortis is employed to make deep cuts on the roller, thus saving the time which the engraver would otherwise be compelled to devote to making these cuts on the first steel die. The parts which it is desired shall not be attacked are painted by hand with an acid-proof paint. Pentagraphy is a system of tracing objects by means of diamond or steel points upon a varnished roller, and then submitting the roller to the etching process, the nitric acid attacking the roller where the bituminous varnish has been scraped off.

609.

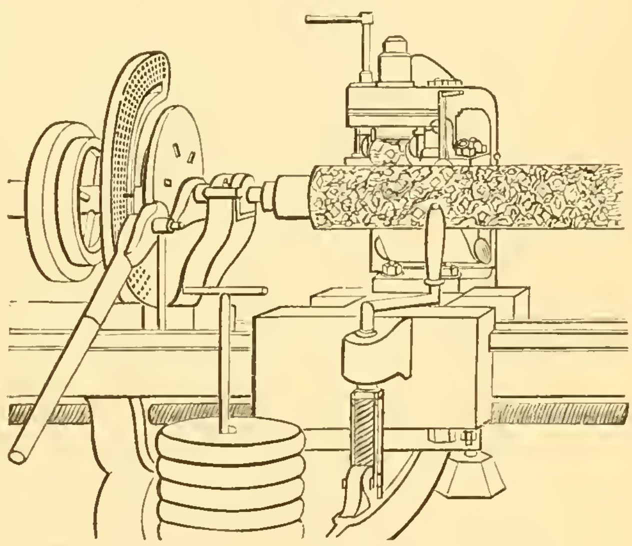
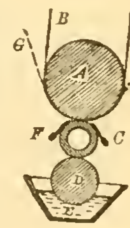


Fig. 609 represents the machine used in engraving the copper cylinders used in machine printing. In the printing-machine the cylinders upon which the pattern is engraved, one cylinder for each color, are mounted on a strong frame-work, so that each cylinder revolves against two other cylinders, one of which is covered with woolen cloth, and dips into a trough containing coloring matter properly thickened, so that, as it revolves, it takes up a coating of color and distributes it over the engraved roller, which transfers the pattern to the cloth. The cloth to be printed passes over a large iron drum covered with several folds of woolen cloth, so as to form a somewhat elastic printing surface: an endless web of blanketing is made to pass round this drum, which serves as a sort of guide, and defence, and printing surface to the calico which is being printed. The superfluous color is removed from the engraved roller by a sharp-edged knife or plate, usually of steel or gun-metal, called the *color-doctor*, so arranged that the color scraped off shall fall back into the trough; another plate of steel removes the fibres which the roller acquires from the calico. This arrangement will be understood from Fig. 610, in which *A* is the iron drum over which passes the blanket *B*; *C* is the calico which passes over the engraved roller below; *D* is the color-roller, *E* the color, *F* the color-doctor, and *G* the lint-doctor. To realize an idea of a 12 or 20 colored printing machine, it is only necessary to imagine a large circle and a plurality of repetitions of this mechanism arranged around its circumference.

610.



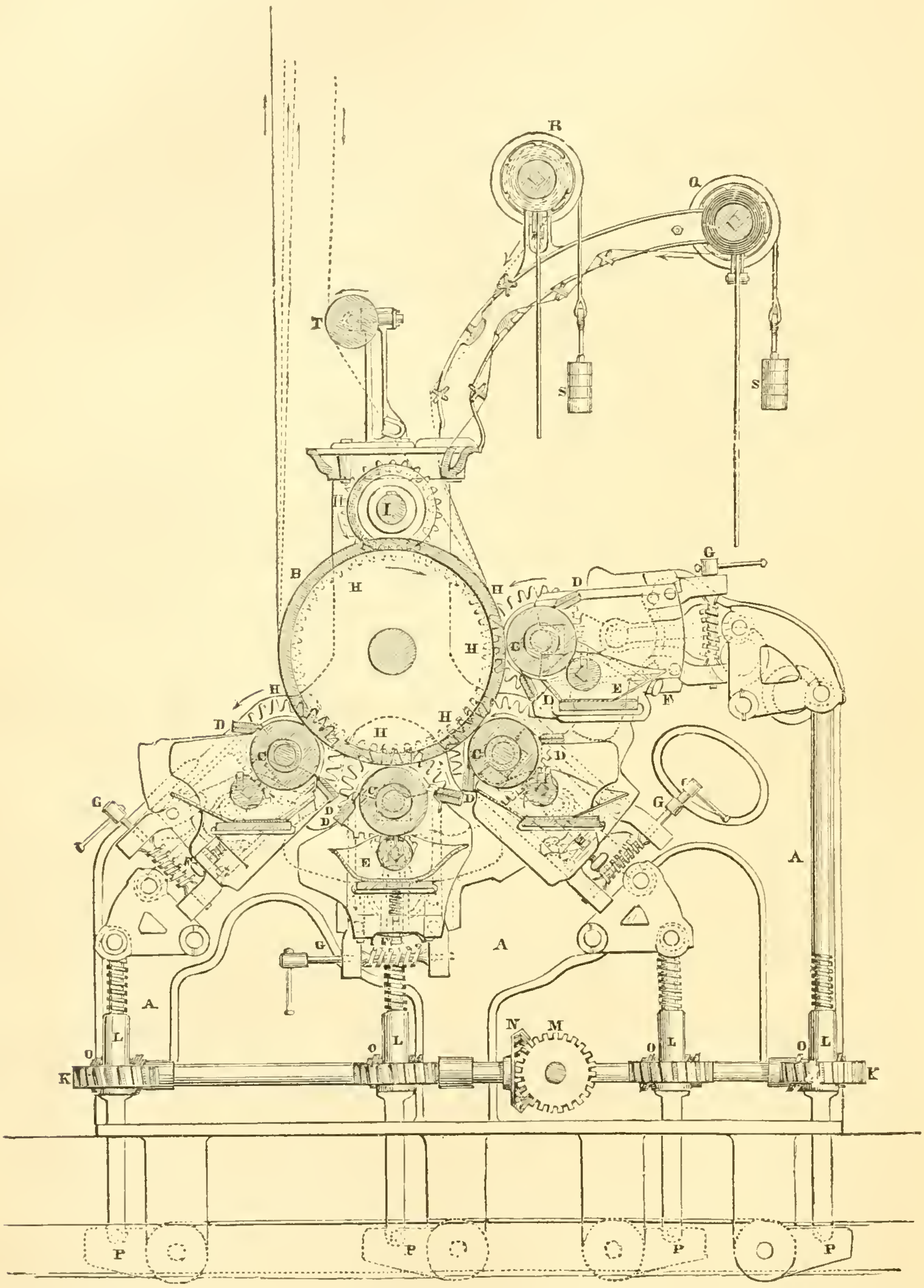

In the four-color printing-machine, Fig. 611, the pressure is normal, in all the engraved rollers, by means of the levers *P*. These rollers are turned by a belt communicating with the prime mover. The regulators are adjusted by screws, to which are attached hands, indicating upon dials the space to be run by the rollers in order to reach the regulators: this is known without stopping the works. The engraved rollers can be brought up to the pressing-cylinder, or withdrawn from it, without changing the places of the color-vessels or of the scrapers; for all the different pieces, fixed against the pillows on the turning pieces of the engraved rollers, move with these last. Finally, there is an apparatus placed behind the under cloth, the intermediate cloth, and the stuff to be engraved, by which the workman governs these three pieces at will.

The vessels in which the rollers dip are made of copper or wood. It is necessary to keep them supplied with a constant quantity of printing material, for the rollers would soon only skim over the surface of the fluid and leave but a feeble impression; to this end a reservoir pours a continual supply. A partition is placed in a position which enables it to clear the roller of the froth with which its surface may be covered.

Fig. 612 shows the construction of a machine for printing 8 colors, and Fig. 613 one for printing 20 colors. The surface-roller machine executes similar styles of work to those produced by the per-

rotine described below. Here the pattern cylinder is in relief. In Fig. 612, *A* is the frame-work; *B* the bowl or cylinder, which is hollow, and made with arms inside; *C C* are the surface-rollers, supplied with color by the endless web or sieve *F* revolving around the wooden tension rollers *D D*

611.



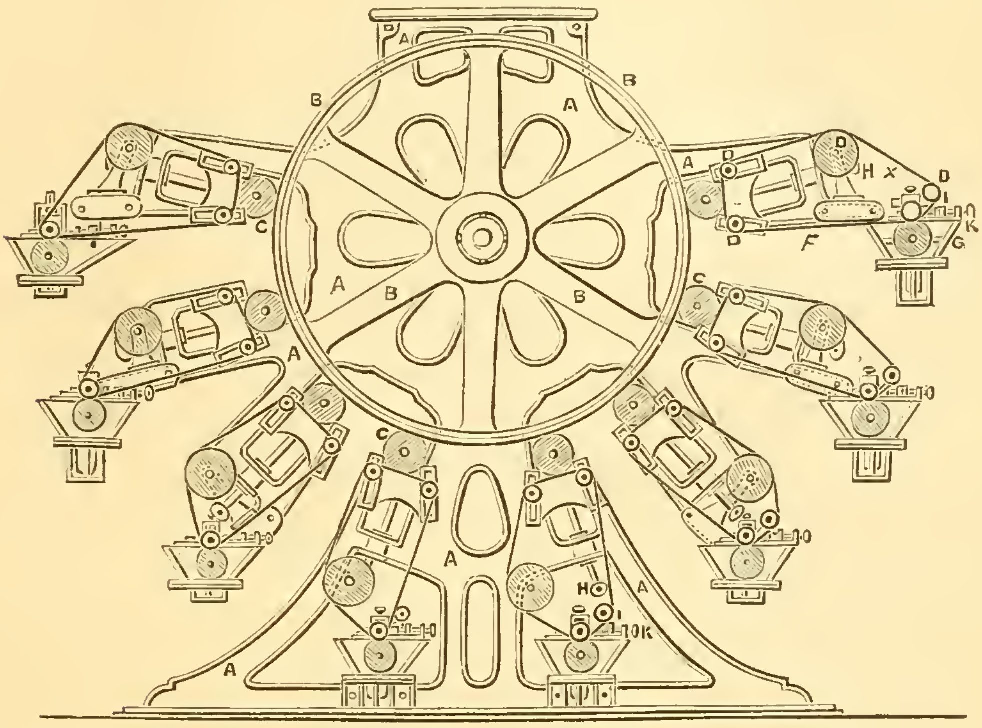
*A A A*, framework.
*B*, pressing cylinder.
*C C C C*, engraved cylinders.
*D D D D*, scrapers.
*E E E E*, vessels containing the coloring matter: they are raised and lowered at pleasure, by the screws *F*.
*G G G G*, endless screws, guiding the regulators.
*H H H H H H H*, pinions and wheels which turn all the machinery.

*I*, a shaft communicating with the moving power.
*K K K K*, wheels adapted to the female screws *L L L L*, which put the levers in communication with the pillows of the rollers.
*M*, a wheel communicating with the driving-power, whose office is to press the rollers; it also moves the wheel *N*, and the endless screws *O O O O*, which are engaged with the wheels *K K K K*.

*P P P P*, levers which are loaded with weights in proportion with the pressure required: they are situated beneath the floor.
*Q*, the cylinder round which the cloth to be printed is rolled.
*R*, the cylinder round which the intermediate cloth is wound.
*S*, a weight which keeps the cloth stretched on the cylinders *Q R*.
*T*, a roller used to give an inclination to the cloth when printed, and regulate the speed.

*E*. The roller *E* is screwed down so as to press the sieves on the furnishing-roller, which revolves in the copper color-box *G*. The two tension-rollers next to the surface-roller move in slides, so that, by means of screw *H*, the sieve can be pressed against the surface-roller; on leaving the furnishing-

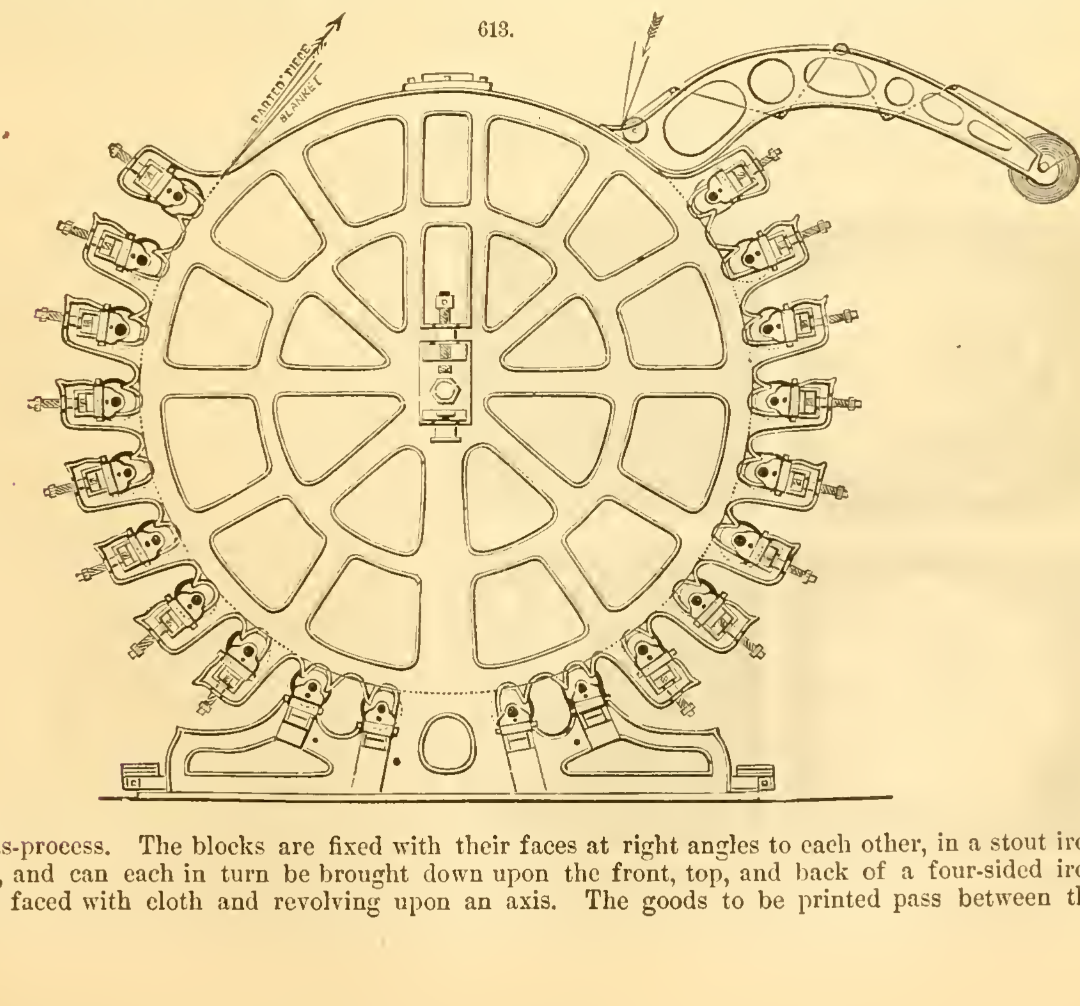
612.




roller, the sieve is wiped by the doctor *I*. The surface-machine is well adapted for woolen fabrics, and the colors, being laid on the top of the cloth, have a very rich appearance.

The perrotine machine executes a style of work very similar to hand-block printing. Wooden blocks varying from 2½ to 3 feet in length, according to the width of the pieces, and varying in breadth from 2 to 5 inches, have the pattern engraved in relief on their surface. By the gas-process illustrated in Fig. 614, the graving-tool is heated to redness by means of a small gas-burner, and destroys all parts of the surface except those left in relief. Fig. 615 represents designs produced by

613.




the gas-process. The blocks are fixed with their faces at right angles to each other, in a stout iron frame, and can each in turn be brought down upon the front, top, and back of a four-sided iron prism, faced with cloth and revolving upon an axis. The goods to be printed pass between the

prism and the pattern-block, and receive the impressions in succession. The effect of these successive applications in producing the different shades of a flower is represented in Figs. 615, 616, and 617. The blocks are forced down upon the calico by means of springs, so as to imitate the pressure of the hand of the block-printer.

614.

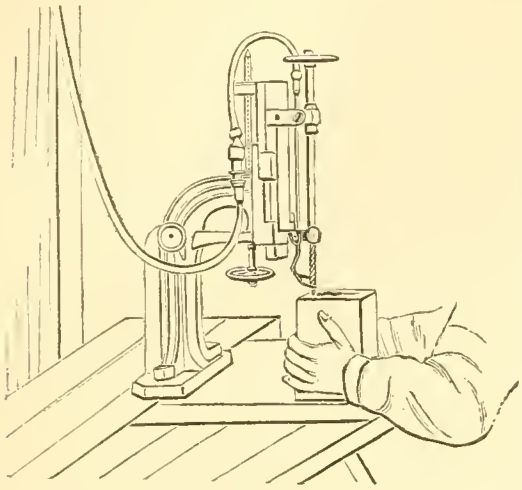
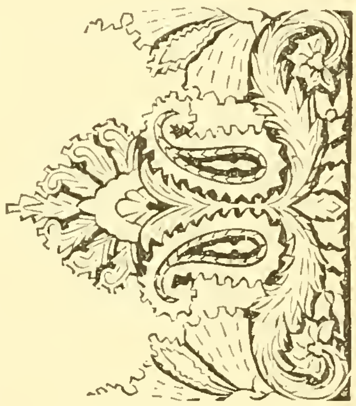


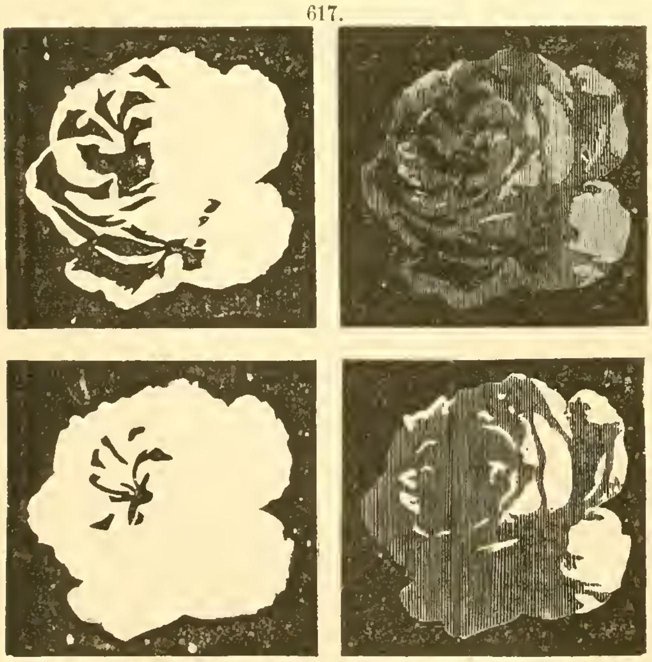
Fig. 618 represents an eight-color perrotine machine. $a^1$ $a^2$ $a^3$ $a^4$ $a^5$ are the forms, fastened to iron supports, which are carried by the pressure-bars $b^1$ $b^2$ $b^3$ $b^4$ $b^5$. These latter execute an interference motion, which, as may be examined in the case of the pressure-bar $b^1$, is produced by the two crank-pins *c* and *d*—of which *c* makes twice as many revolutions in a given time as *d*—by the joint-levers *e* and *f*, and the stay or frame *g*. Through the rotation of the crank-pins *c* and *d*, the forms are at first fully drawn back, while, by means of a special combination of levers, all the color-plates *h* are placed between the forms $a^1$ $a^2$ $a^3$ $a^4$ $a^5$, and the printing-tables $i^1$ $i^2$ $i^3$ $i^4$ $i^5$. The color-plates are flat cast-iron plates covered with an elastic material, upon which color is transferred while passing the color-rollers $k^1$ $k^2$ $k^3$ $k^4$ $k^5$. The printing-tables, which are also covered with an elastic material, serve as a support for the stuff during the operation of the printing. The stuff to be printed is rolled off the beam *l*, and, passing over one stretching-roller, three stretching-bars, and a wooden guide-roller, is carried by means of the needle-rollers $m^1$ $m^2$ $m^3$ $m^4$ $m^5$ over the printing-tables, passing out of the machine at *w*, and being then led off to a drying apparatus. With a further rotation of the crank-pins, the pressure-bars advance so far only that the forms touch the color-plates, the embossed designs of the former thus being caused to receive color from the latter. The pressure-bars $b^1$ $b^2$ $b^3$ $b^4$ $b^5$ are now withdrawn with the form covered with color, while the color-plates pass back in the mean time to the coloring apparatus, where they receive a fresh supply. Another rotation of the crank-pins advances the forms close to the printing-table, and presses the design covered with color upon the stuff in front of the printing-tables. After this operation the forms are drawn back, the color-plates are again placed between the forms and the printing-tables, and the same operations are repeated during the following rotations of the crank-pins.

615.



616.

617.



During the time the coloring-plates are moved up and down again, or, in other words, during the time in which the forms are not in contact with the stuff, the latter advances as much as the width of the form (length of guide), so that the next impression takes place close behind the one previously executed.

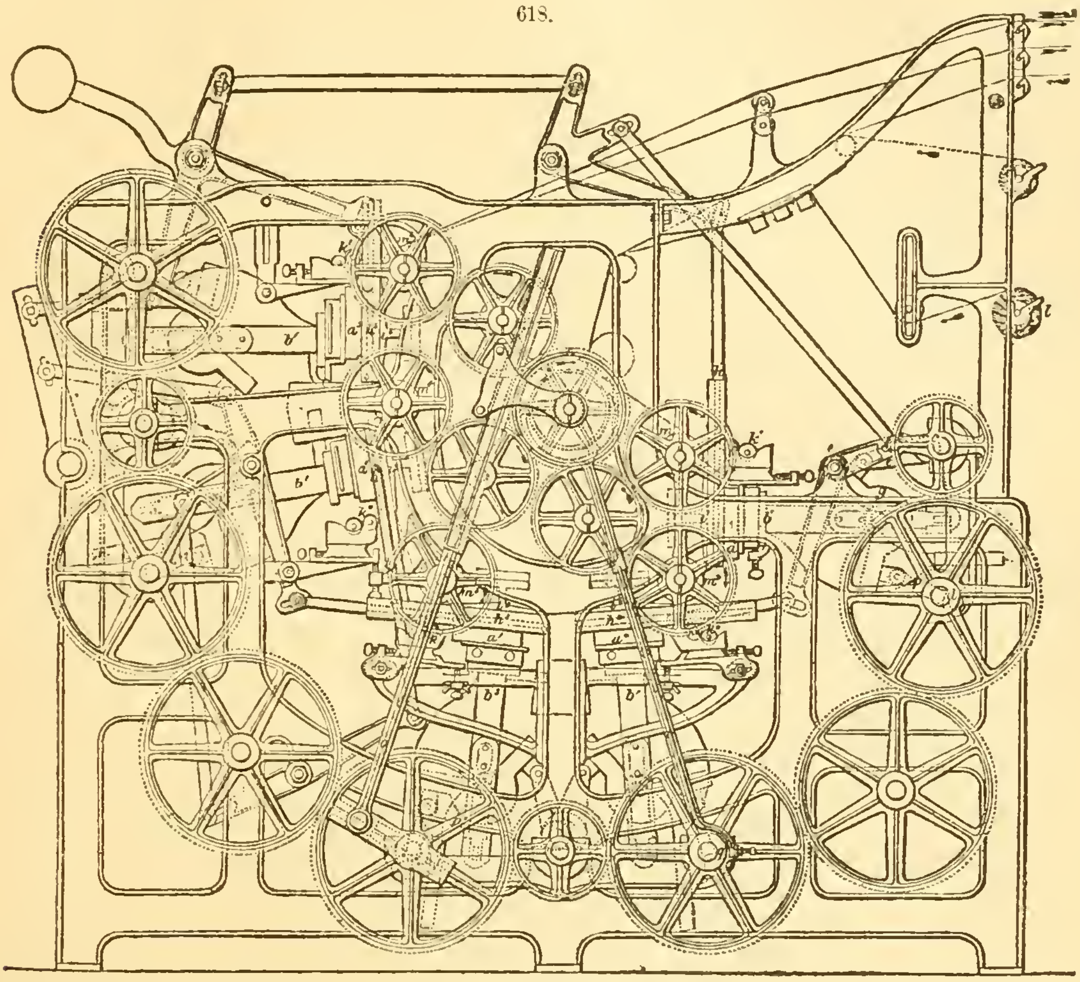
By a special contrivance, it is rendered possible to cause each form to strike the stuff on one and the same place twice successively, after having taken up color in the intermediate time.

There are numerous machines connected with calico-printing for descriptions of which the reader is referred to the works of reference cited below. Among them may be noted the pentagraph for reproducing several times at once the lines of an enlarged pattern on the rollers; the color-pans and dye-vats, washing apparatus, construction of the ageing-room, and steaming-chests. Good brief descriptions of many of these appear in the article on calico-printing in the "Encyclopædia Britannica," 9th edition.

All the finishing processses to which calico is subjected have one common end, namely, to fill up

the interstices which exist in the fabrics, and thus give them a more glossy and substantial appearance. This is effected by filling the cloth with starch, to which sulphate of lime or baryta is often added to give factitious weight and solidity. The various operations are stretching (see CLOTH-FINISHING MACHINERY), bleaching in a chlorine solution, which is followed by steaming, water-mangling, and drying. In the starching machine, a roller revolves in a starch solution and carries it up to the cloth, which passes around upper rollers, where it becomes saturated by the squeezing action produced. After starching, the goods are again dried, sprinkled, and calendered. (See CALENDER.) Lastly, each piece is folded. (See CLOTH-FINISHING MACHINERY.)

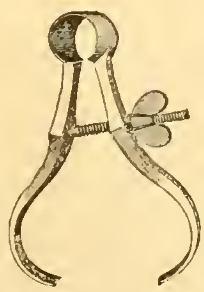
618.



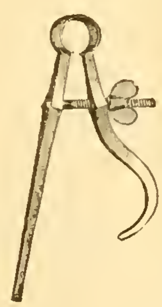
*Works for Reference.*—"Traité Théorique et Pratique de l'Impression des Tissus," Persoz, Paris, 1846; "A Practical Treatise on Dyeing and Calico-Printing," anonymous, New York, 1846; "A Dictionary of Calico-Printing and Dyeing," O'Neill, London and Manchester, 1862; "A Practical Handbook of Dyeing and Calico-Printing," Crookes, London, 1874 *; "Dyeing and Calico-Printing," Calvert, London and New York, 1876. For details of various improvements in calico-printing and dyeing, see files of the *Textile Colourist*, an English monthly periodical published during 1876 and 1877.

619.


620.



621.



622.

CALIPERS. An instrument for measuring the diameter or thickness of objects. Calipers are made in a variety of forms, of which several examples are given in the annexed engravings. Fig. 619 is a pair of inside and outside calipers combined, the curved legs gauging the exterior of the work, as at *B*, and the straight legs, the ends of which are bent, measuring the interior, as at *A*. Fig. 620 shows the usual form of spring calipers, the legs being held apart by the bow-spring at the junction, and brought together by the screw. A modification of this tool is shown in Fig. 621, which is adapted for the measurement of keyholes. There are several kinds of registering calipers, one form of which is represented in Fig. 622. On one leg is attached a scale, and on the other a pointer, which indicates the amount of separation of the leg-points, and consequently the thickness

* This work contains a very complese series of bibliographical references to the literature of dyeing, and, with Dr. Calvert's book, is illustrated by actual samples of calico, exhibiting the effects of various dyes and methods of printing.

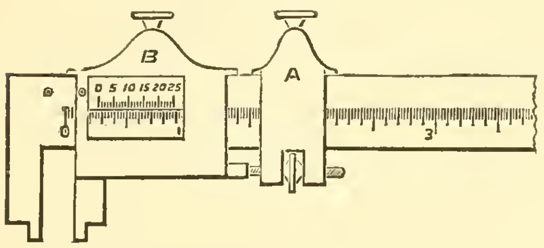
of the object under measurement. Registering calipers for measuring standing or cut timber have arms about 13 feet long, between which is an arc denoting the quarter girth in feet and inches.

Calipers may be employed to mark off the centres of holes, or to try if a centre already existing is in the exact centre of the hole. Or they will mark off a face so that it will fit another face, whether it be regular or irregular, the curved point being kept against the irregular face, and the point describing (by moving the compass along) a similar line on the face to be fitted. They will answer for many of the uses to which a scribing-block is put; and being lighter and more easily handled, and, furthermore, capable of doing duty without the use of a surface or scribing-plate, they are in such cases far preferable. The legs may be crossed so that the curved point inclines to the straight point, in which position they will mark the centres of shafts or rods, either round, square, or any other shape, or try such centres, when they already exist, more accurately than can be done by any other tool. They will, in this case, mark off a line at the distance to which they are set round any surface; they are employed to mark off keyways, or the taper of a gib when the key and one edge of the gib are placed, and for a variety of other uses too numerous to recapitulate, being among the most useful tools the fitter can possibly possess.

*Vernier Calipers.*—Figs. 623 and 624 represent the sides of vernier calipers for very accurate measurement, made by Messrs. Darling, Brown, and Sharpe. One side reads to thousandths of inches,

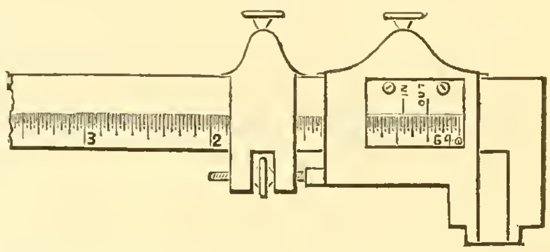
623.

FRONT SIDE.



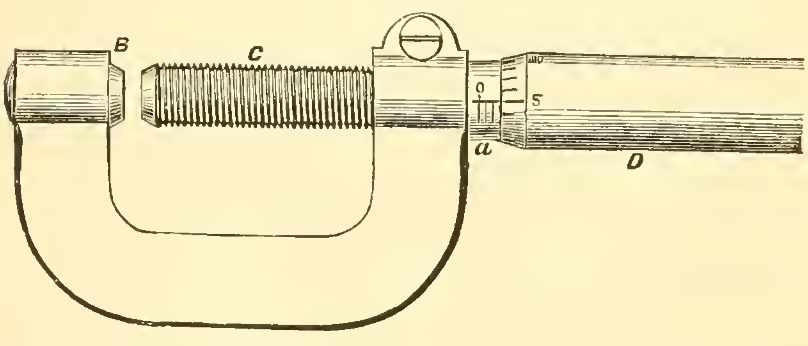

624.

BACK SIDE.

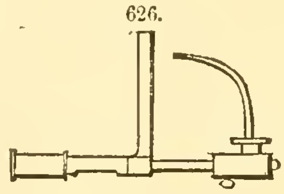



the other to sixty-fourths and fiftieths of inches. Both inside and outside calipers are provided, and also points to transfer the distance with dividers. The instruments are of steel, with tempered points and ground jaws. The method of reading the instrument is as follows: On the bar is a line of inches numbered 0, 1, 2, &c., each inch being divided into ten parts, and each tenth into four parts, making forty divisions to the inch. On the sliding jaw is a line of division (called a vernier, from the inventor's name) of twenty-five parts, numbered 0, 5, 10, 20, 25. The twenty-five parts on the vernier correspond in extreme length with twenty-four parts, or twenty-four fortieths, on the bar; consequently each division on the vernier is smaller than each division on the bar by one thousandth part of an inch. If the sliding jaw of the calipers is pushed up to the other, so that the line marked 0 on the vernier corresponds with that marked 0 on the bar, then the two next lines to the right will differ from each other by one thousandth of an inch; and so the difference will continue to increase,

625.




626.



one thousandth of an inch for each division, till they again correspond at the line marked 25 on the vernier. To read the distance, with the calipers open, commence by noticing how many inches, tenths, and parts of tenths the zero point on the vernier has been moved from the zero point on the bar; now count upon the vernier the number of divisions, until one is found which coincides with one on the bar, which will be the number of thousandths to be added to the distance read off on the bar. The best way of expressing the value of the divisions on the bar is to call the tenths one hundred thousandths (.100), and the fourths of tenths, or fortieths, twenty-five thousandths (.025). Referring to Figs. 623 and 624, it will be seen that the jaw is open two tenths and three quarters, which is equal to two hundred and seventy-five thousandths (.275). Now suppose the vernier was moved to the right so that the tenth division should coincide with the next one on the scale, which will make ten thousandths (.010) more to be added to two hundred and seventy-five thousandths (.275), making the jaws to be open two hundred and eighty-five thousandths (.285). In making inside measurements with the vernier, two tenths or two hundred thousandths (.200) of an inch should be added to the apparent reading for the bigness of the caliper-points. When the other side of the instrument is used, no deduction is necessary, as there are two lines, one indicating inside and the other outside measurement.

In using this instrument, the set-screw at $A$ is set up tight, while that at $B$ is adjusted so as to maintain $B$ a sliding fit upon the bar. The calipers should not be forced upon the work, the measure-

ment being accurate when the faces of the calipers just touch the object, an easy moving fit, so that the instrument may be moved by the finger and thumb upon the work without any play between the calipers and the work.

*Micrometer Calipers.*—This instrument, Fig. 625, forms a reliable and convenient substitute for the vernier calipers for all measurements less than one inch. The main piece of the calipers is bow-shaped, with a projecting shank *a*, into which is fitted the screw *C*, which is accurately cut with a thread of 40 pitch. The shank *a* has a line of graduations of the same pitch as the screw *C*. The hollow cap *D*, which is firmly attached to the right-hand end of the screw *C*, fits upon the outside of the shank *a*. One revolution of this cap opens the calipers twenty-five thousandths of an inch. Parts of a revolution are shown on the line of graduations upon the circumference of the beveled end of the cap *D*, the value of each graduation being one thousandth of an inch in the opening of the calipers. Thus, three whole turns and one-fifth of a turn would equal eighty-one thousandths of an inch, inasmuch as three turns equal twenty-five thousandths, and one-fifth of a turn (or five of the circular graduations) equals five thousandths, making altogether eighty-one thousandths of an inch. Though graduated to read to thousandths of an inch, half and even quarter thousandths are easily obtained, and measurements are read without the use of a glass. It is provided with screws for adjustment and for holding it securely at any given size. Being made wholly of steel, all the parts are durable, the points of contact also being tempered. It is small, light, well adapted for use as a pocket tool, and meets many special requirements of fine implement makers.

627.

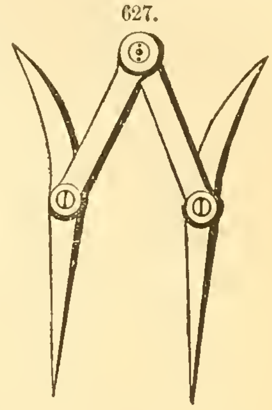


Fig. 626 represents calipers used for the measurement of shells in order to determine the thickness of the metal on the great circle at right angles to the axis of the fuse. A quite handy tool for the wood or metal worker is the universal compass calipers represented in Fig. 627. The legs have pivoted to them revolving caliper-ends, so that the device can be used either as a plain scriber, scribing compass, or inside or outside calipers. J. R.

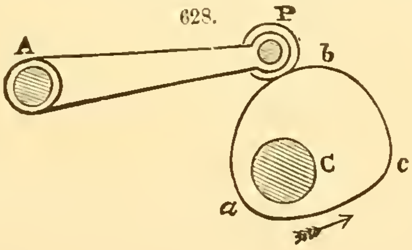
CALLIOPE. A musical instrument, consisting of a number of steam-whistles attuned to produce different notes. The whistles are operated from a keyboard, or from a barrel rotated by mechanism, and having suitably disposed pins which engage with devices in communication with the whistles.

'CALORIC ENGINE. See Engine, Air.

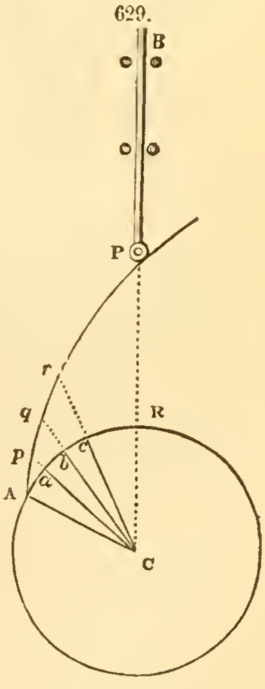
CALORIMETER. See Electro-galvanic Batteries.

CAM. A curved plate or groove which communicates motion to another piece by action of its curved edge. When the cam shown in Fig. 628 rotates in the direction of the arrow, the roller *P* at the end of the lever *A P* will be raised gradually by the curved portion *a b*, will be held at rest while *b c* passes underneath it, and finally will be allowed to fall by the action of *c a*. The circular motion being uniform, the reciprocating piece may also move uniformly, or its velocity may be varied at pleasure. Suppose that the reciprocating piece is a sliding bar, whose direction passes *through the centre of motion* of the cam-plate; take *C*, Fig. 629, as this centre, let *B P* represent the sliding bar, and let *A* be the commencement of the curve of the cam-plate. The curve *A P* may be set out in the following manner: With centre *C* and radius *C A* describe a circle, and let *B P* produced meet its circumference in the point *R*. Divide *A R* into a number of equal arcs, *A a*, *a b*, *b c*, etc. Join *C a*, *C b*, *C c*, etc., and produce them to *p*, *q*, *r*, etc., making *a p*, *b q*, *c r*, etc., respectively equal to the desired movements of *B P* in the corresponding positions of the cam-plate; the curve *A p q r . . . P* will represent the curve required.

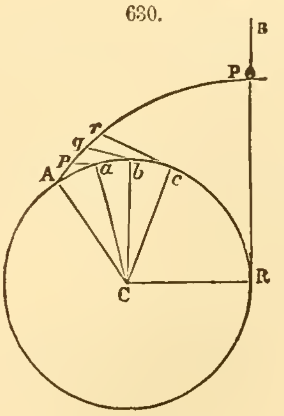
628.




629.




630.



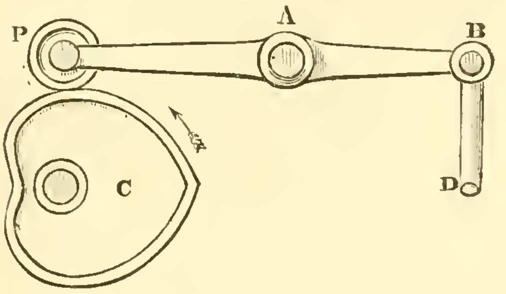

We will next examine the case where the centre of motion of the cam-plate lies upon one side of the direction of the sliding bar, and we shall find that the method of setting out the curve changes accordingly. Suppose that the direction of *B P*, Fig. 630, passes upon one side of the centre of motion *C*; draw *C R* perpendicular to *B P* produced; describe a circle of radius *C R*, and conceive the motion to begin when *A* coincides with *R*. As a matter of theory such an extreme case is possible, and we will imagine it to exist in order to obtain the equation which represents the complete curve. Practically, the cam would be more effective in straining the bar than in moving it when the point *P* was near to the point *R*. Divide *A R* into the equal intervals *A a*, *a b*, *b c*, etc., but now draw *a p*, *b q*, *c r*, etc., tangents to the circle, and equal in length respectively to the desired movements of *B P* during the corresponding periods of motion of the cam-plate. The curve *A p q r . . . P* will be that required.

*The heart-wheel* has been much used in machinery, and is formed by the union of two similar and

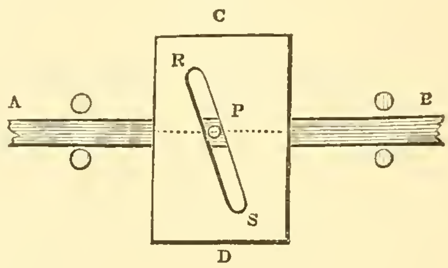
equal cams of the character discussed above. A curved plate *C*, Fig. 631, shaped like a heart, actuates a roller *P*, which is placed at the end of a sliding bar, or which may be attached to a lever *P A B*, centred at some point *A*, and connected by a rod *B D* to the reciprocating piece. The peculiar form of the cam allows it to perform complete revolutions, and to cause an alternate ascent or descent of the roller *P* with a velocity which may be made quite uniform. Since a cam of this kind will only drive in one direction, the follower must be pressed against the curve by the reverse action of a weight or spring.

Hitherto we have considered the cam to be a plane curve or groove; but there is no such restriction as to its form in practice. Let us examine the following very simple case, as well as the exten-

631.

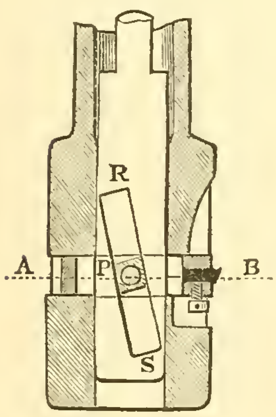



632.

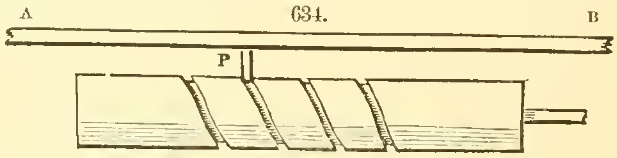



sion of which it admits: *C D*, Figs. 632 and 633, is a rectangle with a slit *R S* cut through it obliquely; a pin *P* fixed to the sliding bar *A B* works in the slit. If the rectangle *C D* be moved in the direction *R S*, it will impart no motion to the bar *A B;* but if it be moved in any other direction, the pin *P* will be pushed to the right or left, and a longitudinal movement will be communicated to the bar *A B*. Next let *C D* be wrapped round a cylinder; it will form a screw-thread, and the revolution of the cylinder upon its axis will be equivalent to a motion of the rectangle at right angles to the bar. We shall have, therefore, by the arrangement in Fig. 634, a continuous uniform rectilinear motion of the bar *A B* during the revolution of the cylinder upon which the screw-thread is traced. If the pitch of the screw be constant, the motion of *P B* will be uniform, and any change

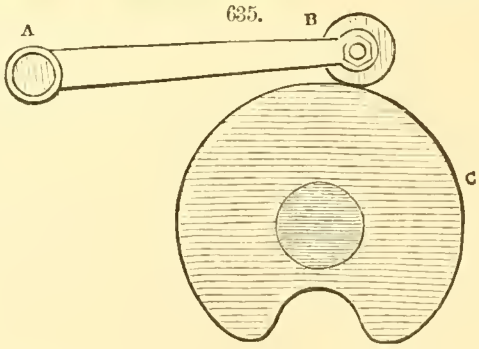
633.




634.




635.

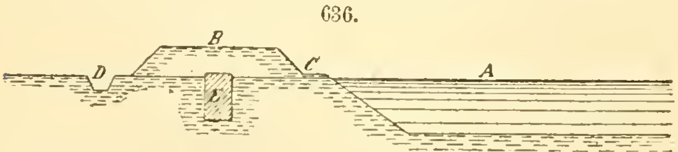



of velocity may be introduced by a proper variation in the direction of the screw-thread. If the screw be changed into a circular ring, *A B* will not move at all.

Cams are employed when it is required to effect a movement with extreme precision. Thus in the machine of Mr. Applegath for printing newspapers, the accuracy with which the sheet is delivered is very remarkable, and is insured by the assistance of the cam represented in Fig. 635. As *C* revolves, the roller at *B* drops into the hollow of the plate, thereby determining the fall of the lever *A B*, and by it the fall also of another roller which starts the paper upon its course to the printing-cylinder. See "Elements of Mechanism," Goodeve, London and New York, 1877.

CANALS. Canals are open channels of water for the purposes of navigation, water-supply for cities and manufactories, for drainage, for irrigation, etc. The form and size of the canal will depend upon the purposes to which it is to be applied: for navigation, on the size of the boats and the amount of traffic; for water-supply, drainage, etc., on the amount of water to be supplied or discharged.

636.




Navigable canals may be divided into two classes: Class I. Canals which are on the same level throughout their entire length, as those which are found in low level countries; Class II. Canals which connect two points of different levels, which lie either in the same valley, or on opposite sides of a dividing ridge.

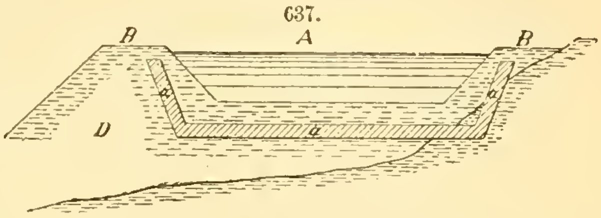
Canals of class I. are found in broken countries, in which it is necessary to divide the entire length of the waterway into several level portions, the communication between which is effected

by some artificial means. The cross-section of this class presents usually a waterway or channel of a trapezoidal form, with an embankment on each side, raised above the general level of the country, and formed of the excavation for the waterway. In Fig. 636, *A* represents the waterway; *B*, tow-paths; *C*, bermes; *D*, side-drains; *E*, puddling of sand or clay.

II. This class will admit of two subdivisions: 1. Canals which lie throughout in the same valley; 2. Canals with a summit level.

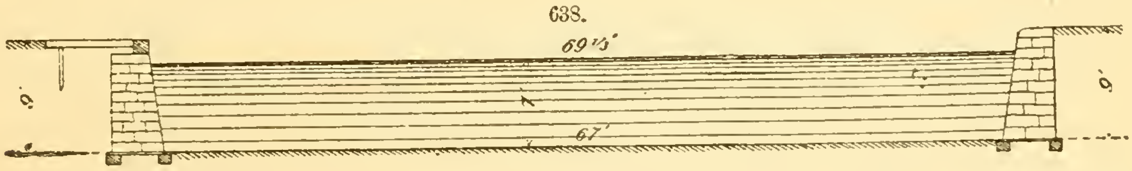
*Cross-section.*—The side formations of excavations and embankments require peculiar care, particularly the latter, as any crevices left when they are first formed, or which may take place by settling, might prove destructive to the work. In most cases, a stratum of good binding earth, lining the waterway throughout to the thickness of about 4 feet, if compactly rammed, will be found to offer sufficient security if the substructure is of a firm character and not liable to settle. Fine sand has been applied with success to stop the leakage in canals. The sand for this purpose is sprinkled in small quantities at a time over the surface of the water, and gradually fills up the outlets in the bottom and sides of the canal. But neither this nor puddling has been found to answer in all cases, particularly where the substructure is formed of fragments of rocks offering large crevices to filtrations, or is of a marly nature. In such cases it has been found necessary to line the waterway throughout with stone laid in hydraulic mortar. A lining of this character, *a*, Fig. 637, both at the bottom and sides, formed of flat stones about 4 inches thick, laid on a bed of hydraulic mortar 1 inch thick, and covered by a similar coat of mortar, making the entire thickness of the lining 6 inches, has been found to answer all the required purposes. This lining should be covered, both at bottom and on the sides, by a layer of good earth, at least 3 feet thick, to protect it from the shock of the boats striking either of those parts.

637.




Although, for the sake of saving expense in aqueducts and bridges, short portions of a canal may be wide enough for the passage of one boat only, the general width ought to allow two boats to pass each other easily. The depth of water and sectional area should be such as not to cause any material increase of the resistance to the motion of the boat beyond what it would encounter in open water. The following are the general rules which fulfill these conditions: Least breadth at bottom

638.



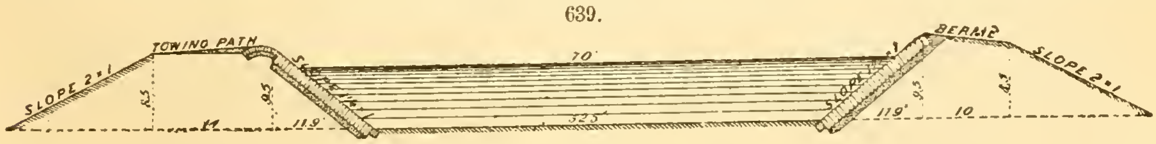

= 2 × greatest breadth of a boat. Least depth of water = $1\frac{1}{2}$ foot + greatest draught of boat. Least area of waterway = 6 × greatest midship section of a boat.

The bottom of the waterway is flat. The sides, when of earth (which is generally the case), should not be steeper than $1\frac{1}{2}$ to 1. When of masonry, they may be vertical; but, in that case, about 2 feet additional width at the bottom must be given, to enable boats to clear each other; and if the length traversed between vertical sides is great, as much more additional width as may be necessary in order to give sufficient sectional area.

Figs. 638 and 639 represent cross-sections of the Erie Canal as enlarged—the former through level cuttings and the latter through a city.

All canal embankments should be formed and rammed in thin layers. The surface of the tow-path is usually about 2 feet above the water-level, and is generally abont 12 feet wide. It is made to slope slightly in a direction away from the canal, in order to give a better foothold for the

639.




horses, as they draw in an oblique direction. The slopes are to be pitched with dry stone from 6 to 9 inches thick.

The disposition to be made of watercourses intersecting the line of the canal will depend on their size, the character of their current, and relative positions of the canal and stream. Small brooks which lie lower than the canal may be conveyed under it through an ordinary culvert. If the level of the canal and brook is nearly the same, it will be necessary to make the culvert in the shape of an inverted siphon, and it is therefore termed a broken-back culvert.

Figs. 640, 641, and 642 are respectively top-view, longitudinal section, and cro s-section of a *composite culvert.* Its construction may be briefly described as follows:

The foundation is composed of hemlock timber 6 inches to 12 inches thick, and covered with hemlock plank treenailed to the timber. The spaces between timbers are filled with fine, clean gravel, well puddled in, or with concrete. Sheet-piling from 3 feet to 6 feet long is put down along the upper and lower sides of the foundation.

The sides of the culvert are composed of white oak or white pine, 8 inches to 12 inches wide and 12 inches thick for culverts 2 feet high, and 10 inches to 14 inches wide and 18 inches thick for

culverts 3 feet in height. The timbers are set on edge, and connected with white-oak dovetailed keys 2 inches thick and 4 inches wide, placed once in 5 feet: a white-oak treenail, 2 inches thick, passes through the centre of the timbers, intermediate the keys.

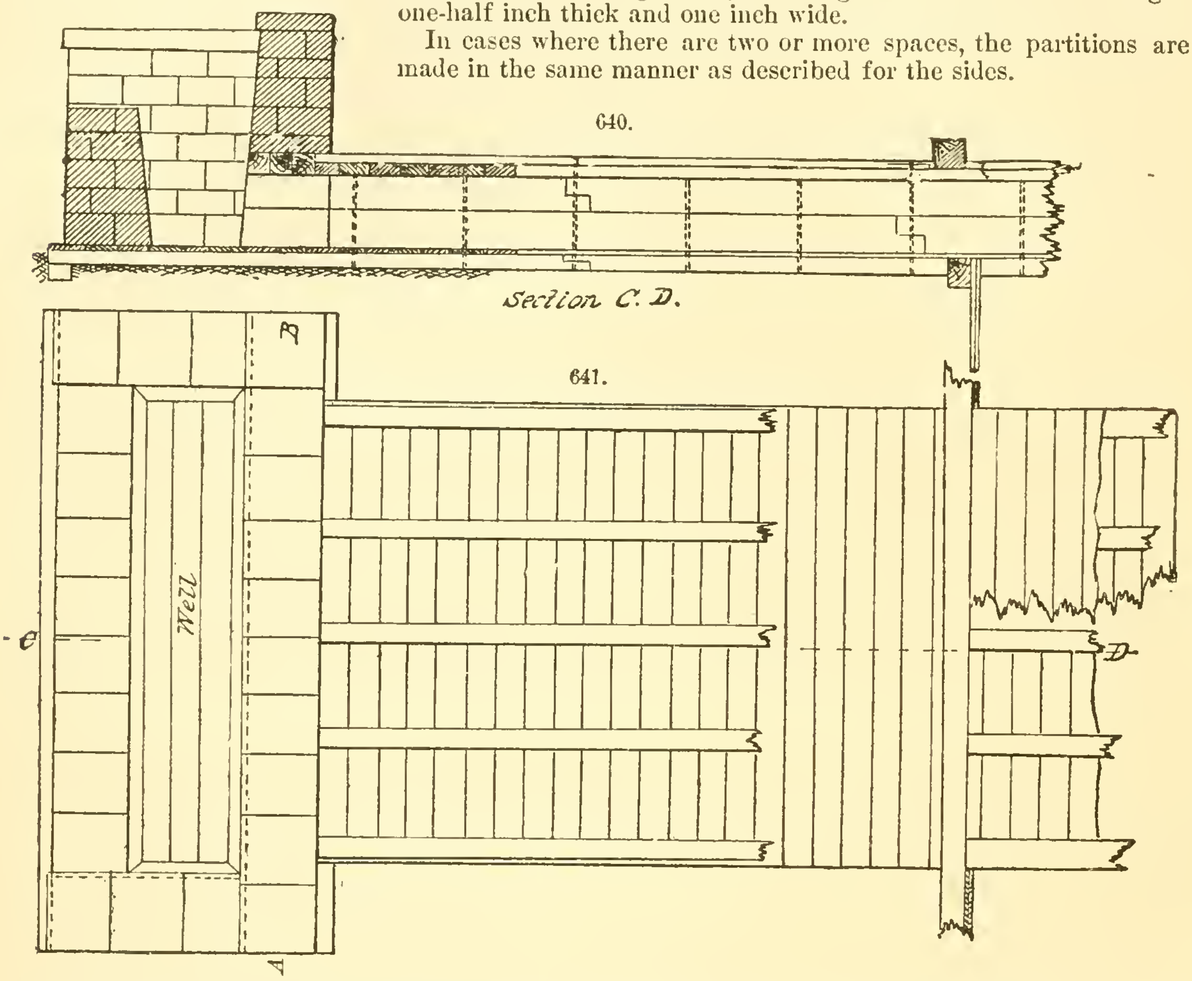
The side timbers are connected with the foundation by treenails and wrought-iron bolts—the bolts being secured at the top of the covering-plank with screw and nut. The side timbers should be not less than 24 feet long each, and be well lapped, and so placed as to break joints with each other. Sometimes they are grooved, and tongued with a white-oak tongue one-half inch thick and one inch wide.

In cases where there are two or more spaces, the partitions are made in the same manner as described for the sides.

640.

Section C. D.

641.



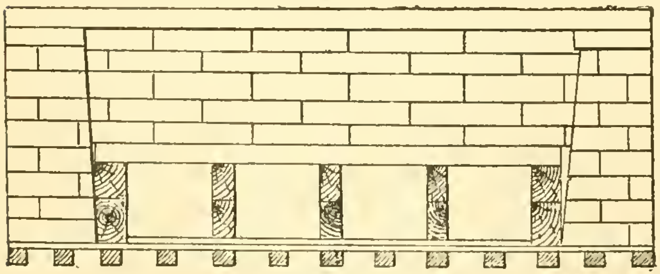

The floors are lined with $1\frac{1}{2}$-inch white-pine plank, treenailed to the foundation timbers.

The top of the culvert is covered with white-pine timbers, from 4 inches to 10 inches thick: these are grooved and tongued as above described, boxed down half an inch, and treenailed to the timbers on which they rest.

If the water of the brook is generally limpid, and its current gentle, it may in the last case be received into the canal. The communication of the brook or feeder with the canal should be so arranged that the water may be shut off or let in at pleasure, in any quantity desired. For this purpose a cut is made through the side of the canal, and the sides and bottom of the cut are faced with masonry laid in hydraulic mortar. A sliding gate, fitted into two grooves made in the side walls, is manœuvred by a rack and pinion, so as to regulate the quantity of water to be let in.

When the line of the canal is intersected by a wide watercourse, the communication between the two shores must be effected either by a canal aqueduct or by the boats descending from the canal into the stream.

642.

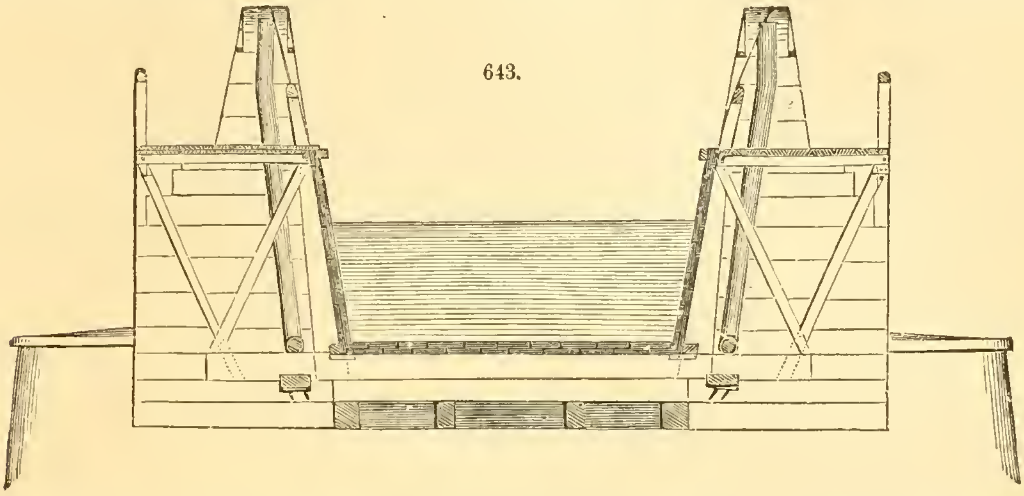


*Section at A B.*

*Canal Aqueducts.*—As an illustration of an aqueduct for the conveyance of a canal across a river, we instance the Wire Suspension Aqueduct over the Allegheny River at Pittsburg, Fig. 643, constructed under the superintendence of John A. Roebling, at the western termination of the Pennsylvania Canal. It consists of 7 spans, of 160 feet each, from centre to centre of pier. The trunk is of wood, and 1,140 feet long, 14 feet wide at bottom, $16\frac{1}{2}$ feet on top, the sides $8\frac{1}{2}$ feet deep. These, as well as the bottom, are composed of a *double* course of $2\frac{1}{2}$-inch white-pine plank laid diagonally, the two courses crossing each other at right angles. The bottom of the trunk rests upon transverse beams, arranged in pairs, 4 feet apart; between these, the posts which support the sides of the trunk are let in with dovetailed tenons, secured by bolts. The outside posts, which support the side-walk and tow-path, incline outward, and are connected with the beams in a similar manner. Each trunk-post is held by

two braces, $2\frac{1}{2} \times 10$ inches, and connected with the outside posts by a double joint of $2\frac{1}{2} \times 10$. The trunk-posts are 7 inches square on top, and $7 \times 14$ at the heel; the transverse beams are 27 feet long and $16 \times 6$ inches; the space between two adjoining is 4 inches. It will be observed that all parts of the framing are double, with the exception of the posts, so as to admit the suspension-

643.



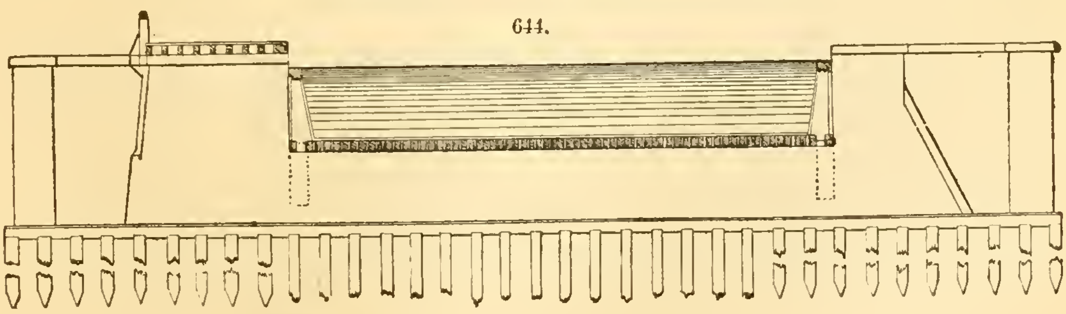
rods. Each pair of beams is supported on each side of the trunk by a double suspension-rod of $1\frac{1}{8}$-inch round iron, bent in the shape of a stirrup, and mounted on a small cast-iron saddle, which rests on the cable. These saddles are connected on top of the cables by links, which diminish in size from the pier toward the centre. The sides of the trunk set solid against the bodies of masonry, which are erected on each pier and abutment as bases for the pyramids which support the cables. These pyramids, which are constructed of 3 blocks of a durable, coarse, hard-grained sandstone, rise 5 feet above the level of the side-walk and tow-path, and measure $3 \times 5$ feet on top, and $4 \times 6\frac{1}{2}$ feet at base. The ample width of the tow-path and foot-path is, therefore, contracted on every pier; but this arrangement proves no inconvenience, and was necessary for the suspension of the cables next to the trunk.

The caps which cover the saddles and cables on the pyramids rise 3 feet above the inside or trunk railing, and would obstruct the free passage of the tow-line; but this is obviated by an iron rod which passes over the top of the cap, and forms a gradual slope down to the railing on each side of the pyramid.

The wire cables, which are the main support of the structure, are suspended next to the trunk, one on each side. Each of these two cables is exactly 7 inches in diameter, perfectly solid and compact, and constructed in one piece from shore to shore, 1,175 feet long; it is composed of 1,900 wires of one-eighth of an inch in thickness, which are laid parallel to each other. Great care has been taken to insure an equal tension of the wires. Oxidation is guarded against by a varnish applied to each wire separately; their preservation, however, is further insured by a close, compact, and continuous wrapping, made of annealed wire, and laid on by machinery in the most perfect manner. The extremities of the cables do not extend *below* ground, but connect with anchor-chains, which, in a curved line, pass through large masses of masonry, the last links occupying a vertical position; the chains below ground are imbedded and completely surrounded by cement. Where the cables rest on the saddles, their size is increased at two points by introducing short wires, and thus forming swells, which fit into corresponding recesses of the casting. Between these swells the cable is forcibly pressed down by three sets of strong iron wedges, driven through openings which are cast in the side of the saddle.

Fig. 644 is a cross-section, and Fig. 645 an elevation of a canal aqueduct. The trunk is constructed of white oak or white pine. The outside stringers are placed so as to embrace the side-post tenons, and give them a firm support. The side-posts are $8 \times 11\frac{1}{2}$ inches at the top, and $8 \times 18$ inches at the bottom shoulder, and placed 3 feet from centre to centre. The corner or end posts are of white oak, and extend down 3 feet into the masonry to give firmness to the corner of

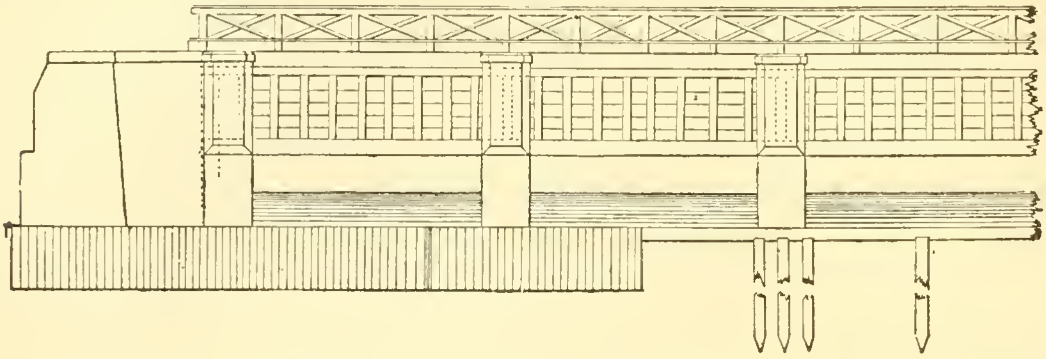
644.



the trunk. A white-pine plate, $10 \times 16$ inches, is framed on top of the posts. The bottom of the trunk and the ends of the floor-timbers in the abutments are covered with a course of 2-inch white-pine plank of good quality, to make water-tight joints. The planks are treenailed to foundation-timbers with treenails 6 inches long, of suitable size to fill an aperture 1 inch in diameter. The

sides are planked with 3-inch white-pine plank, tongued and grooved, and secured to side-posts with treenails 7 inches long. The sides and bottom of the trunk are sometimes braced from recesses cut into the masonry. The tow-path bridge is 12 feet wide, and supported on white-pine stringers. The

645.



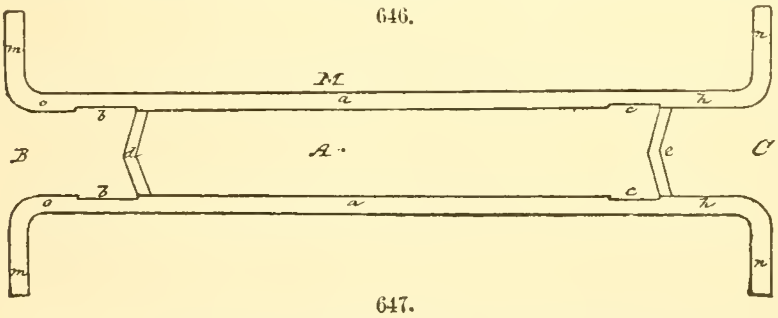
floor is composed of 3-inch white-oak or red-beech timber, treenailed to the stringers. A timber of hard wood, 6 × 8 inches, is placed upon the inside end of the floor to guide the tow-line, and is fastened to the front stringer.

Waste-weirs must be made along the levels to let off the surplus water. The best position for them is at points where they can discharge into natural watercourses. The best arrangement for a waste-weir is to make a cut through the side of the canal to a level with the bottom of it, so that, in case of necessity, the waste-weir may also serve for draining the level. The sides and bottom of the cut must be faced with masonry, and have grooves left in them to receive a stop-plank or a sliding gate, over which the surplus water is allowed to flow, which can be removed if found necessary, either to let off a larger amount of water or to drain the level completely.

Locks.—A lock is a small basin just large enough to receive a boat, in which the water is confined by two upright walls of masonry or timber, and at the ends by two gates, which open and shut, both for the purpose of allowing the boat to pass and to cut off the water of the upper level from the lower, as well as from the lock while the boat is in it.

Fig. 646 represents a plan, *M*, and Fig. 647 a section, *N*, through the axis of a single lock laid on a béton foundation. *A*, lock-chamber; *B*, fore-bay; *C*, tail-bay; *a a*, chamber-walls; *b b*, recesses or chambers in the side walls for upper gates; *c c*, lower gate chambers; *d d*, lift-walls and upper mitre-sill; *h h*, tail-walls; *o o*, head-walls; *m m*, upper wing or return-walls; *n n*, lower wing-walls; *D*, body of masonry under the fore-bay.

646.



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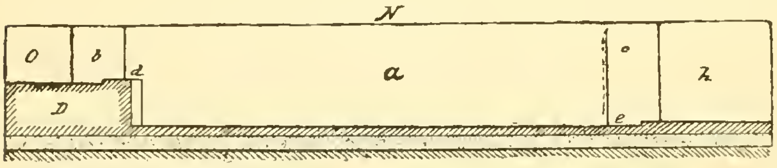


To pass a boat from one level to the other—from the lower to the upper, for example—the lower gates are opened, and, the boat having entered the lock, they are shut, and water is drawn from the upper level by means of valves, to fill the lock and raise the boat; when the operation is finished, the upper gates are opened, and the boat is passed out. To descend from the upper level, the lock is first filled; the upper gates are then opened, and the boat is passed in; these gates are next shut, and the water is drawn from the lock by valves until the boat is lowered to the lower level, when the lower gates are opened and the boat is passed out of the lock.

*Form to be given to the chambers of locks.*—The most convenient is the parallelogram, a little wider than the boats that require to pass, and sufficiently long to admit of the gates being moved with facility. The thickness of straight walls which support earth should be a third of their height, while those which resist the thrust of water should be one-half; if the walls of the chambers of locks have a thickness relative only to the thrust of the earth, they may give way when the earth is put in motion, which often occurs from a slight filtration behind the wall. Gauthey has a rule for finding the thickness to be given to the wall of a basin intended to support water throughout its whole height; and in the chambers of locks it must be remembered that the thrust of the water against the vertical surface is equal to the product of these surfaces by half the height of the water. Call $h$ the height of the wall, $x =$ its thickness: supposing its length to be 1 metre, the acting power will be $1{,}000 \times \frac{1}{2}h^2$; supposing the cubic metre of water to weigh 1,000 kilogrammes, and the centre of impression of this thrust being at a third of the height of the wall, the arm of the lever of the acting power will be equal to $\frac{1}{3}h$. The resisting power will be the wall itself $= h\,x \times 2{,}000$, supposing that the cubic metre of masonry generally weighs 2,000 kilogrammes. The arm of the lever will be half the thickness of the wall $= \frac{1}{2}x$; consequently the momentum of

the acting power will be $1,000 \times \frac{1}{2}h^2 \times \frac{1}{3}h$, and that of the resisting power $2,000 \times \frac{1}{2}h\,x^2$; and as in the state of equilibrium these two powers should be equal, we shall have $167\,h^3 = 1,000\,h\,x^2$, from whence we have $x = \sqrt{0.167\,h^3} = 0.41\,h$; but, as something should always be allowed above the equilibrium, by adding $\frac{1}{5}$ we shall have $x = \frac{1}{2}h$ nearly. Hence it is evident that the thickness of a wall intended to support water should be at least equal to half the height of the water which acts against it.

The length and width of chambers of locks must necessarily be regulated in conformity with the boats used on the canal; these are generally longer and narrower than those on rivers, where the shallows which occasionally occur require flatter bottoms to be given them. With regard to the length of the chambers, it should be such as to enable the gates at the lowest ends to open and shut easily. If the rudders of the boats cannot be unshipped, or occupy any portion of the length of the chamber, then the chambers must be made sufficiently long to prevent them from interfering with the opening of the gate; on which account the most proper rudders for navigable canals are those like broad oars, which can be taken out while passing through the locks.

648.

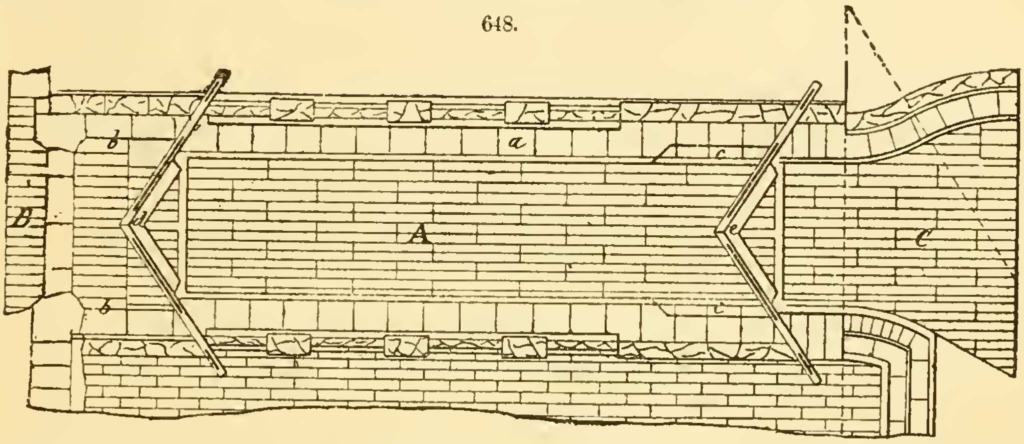
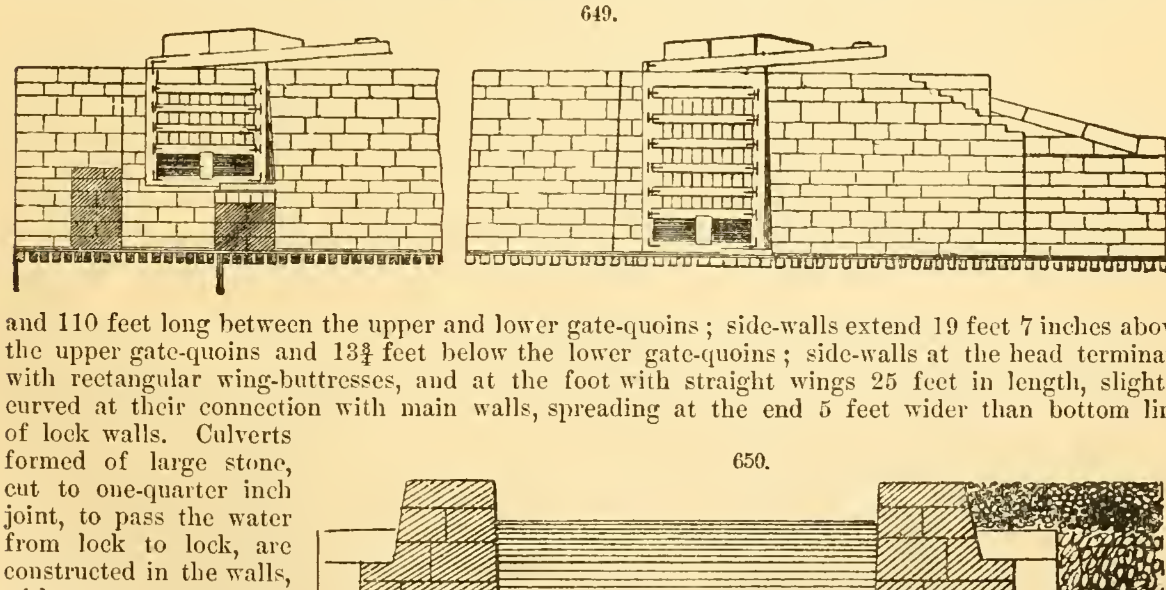


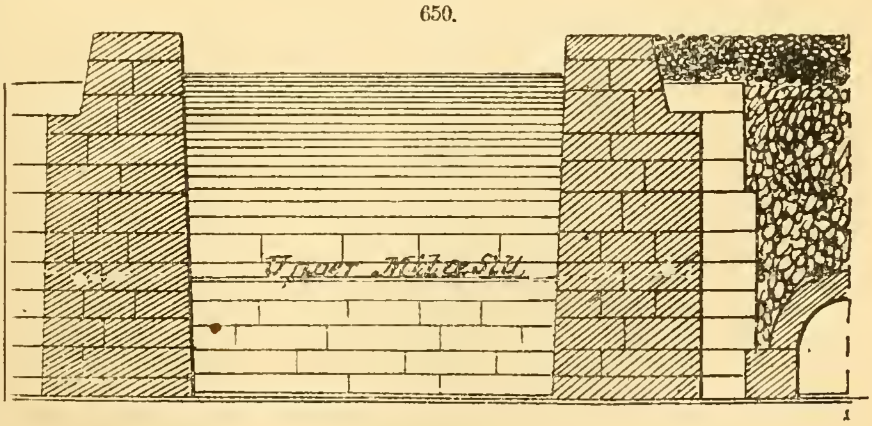

Fig. 648 is a plan, Fig. 649 a longitudinal section, and Fig. 650 a cross-section of the present enlarged form of one-half of a double lock on the Erie Canal. A lock of this description (of 11-feet lift, for example) is constructed as follows: The lock is constructed of hydraulic stone masonry, placed on a timber foundation; the chambers 18 feet wide at the surface of water in the lower level,

649.



and 110 feet long between the upper and lower gate-quoins; side-walls extend 19 feet 7 inches above the upper gate-quoins and 13⅔ feet below the lower gate-quoins; side-walls at the head terminate with rectangular wing-buttresses, and at the foot with straight wings 25 feet in length, slightly curved at their connection with main walls, spreading at the end 5 feet wider than bottom line of lock walls. Culverts formed of large stone, cut to one-quarter inch joint, to pass the water from lock to lock, are constructed in the walls, with proper apertures for valves, rods, and ventilators. The timbers under lower mitre-sill are of white oak, white elm, or red beech; the other foundation and apron timbers are of hemlock. The foundation extends 3 feet above the face of the main wall at the head of the lock, and at the foot 6 inches below end of wing-walls; the length of foundation, exclusive of apron, is 173 feet 3 inches. The spaces between timbers are filled with concrete masonry. Where rock does not occur, sheet-piling is driven 4 to 6 feet deep at the head of the foundation, under each set of gates, at the lower end of the wings and at the lower end of the apron. The sheet-piling is of 2-inch hemlock plank, lined with 1-inch pine boards.

650.



The foundation-timbers are covered with a course of $2\frac{1}{2}$-inch pine or hemlock plank, except a space 3 feet wide under the face-line of each wall, which is covered with $2\frac{1}{2}$-inch white-oak plank. The planks are treenailed with two white-oak treenails at each end, and at every 3 feet in length. The treenails should enter the timbers at least 5 inches, and fill a $1\frac{1}{4}$-inch bore. The platform for upper gates and valves consists of a framework of timber extending across the lock, and raised to within 2 feet 9 inches of canal bottom of upper level. In this platform the valves are inserted; they lie horizontally when closed, and are operated by levers, rods, and shackle-bars from the side of the lock.

The mitre-sills are of white-oak timber 9 inches thick. Each sill is bolted to the foundation or platform timbers with 9 bolts 20 inches long and 1 inch square, ragged and headed.

The main walls, for 17 feet 6 inches in length from the wing-buttresses at the head, and 33 feet 3 inches of the lower end, are 9 feet 10 inches thick including the recesses, and for the intermediate space 7 feet 10 inches, with 3 buttresses projecting back $2\frac{1}{2}$ feet, and 9 feet long, placed at equal distances apart, leaving spaces 16 feet between them, and having an offset of 6 inches in thickness at 5 feet below the top. The height of the walls is $20\frac{3}{4}$ feet. The chamber-walls each have a batter on the face of half an inch per foot rise to the top of the wall. The quoin stones, in which the heel-posts turn, are not less than $4\frac{1}{2}$ feet in length in the line of the chamber, and cut and formed to a curve of 7 inches radius; the nose is rounded on a radius of $3\frac{66}{100}$ inches, and the heel beveled to the rear of the recess. The quoin stones are alternately header and stretcher. The recesses for the lower gates are 20 inches deep at the top of the wall, 12 feet long, with sub-recesses 9 inches deep, 6 feet high, and 10 feet long, for valve-gates. The wing-buttresses at the head of the lock are 3 feet thick, extend on the bottom to the upper edge of the foundation, and are carried plumb to the whole height of the main wall. The breast-wall commences $5\frac{1}{4}$ feet below the upper end of the foundation, and extends across from side wall to side wall; it is 5 feet wide and 11 feet high, finished with cut-stone coping. The wing-walls, at the point where they join the main walls, are 7 feet 10 inches, and at the ends 6 feet 7 inches thick on the foundation; at 4 feet below the top of the wall an offset is made. The face-stone of the masonry is laid with upper and lower beds parallel, with joints not to exceed one-quarter of an inch.

*Gates of locks* are composed of two posts placed vertically, and united by horizontal rails; the former, being supported throughout their height, are not subject to much wear, although they are of larger scantling than the other timbers of the gate, which is necessary, as they sustain the entire framework. The horizontal rails resist the weight, and as that weight is greater where the rails are placed below the level of the water, it would seem natural that their dimensions should vary in proportion to the weight. To determine these dimensions, it must be recollected that the thrust of water against vertical surfaces is equal to the weight of a prism of water having its surface as a base, and its height half that of the water. It must next be considered that the rails of the gate are at least 26 inches apart and 38 inches from centre to centre, so that, on account of the casing of plank in the first instance, 12 inches of height support 26 inches of water, and in the second 38 inches. The weight supported by each rail will be found by multiplying their length, the interval from one to the other, the height of the water above the centre of the rail, and the whole by 62 lbs., the weight of a cubic foot of water; the product of these measures will be the number of pounds which the rails ought to support throughout their whole length.

Timbers from 4 to 5 inches square would be sufficient for small gates, and for larger from 8 feet 6 inches to 10 feet 6 inches of fall; with a width of 17 feet between the hanging-posts, the rails would be sufficiently strong if from 7 to 8 inches square, putting six rails in the height. They are generally from 9 to 10 inches at least, which is double the strength required; it is true that the gates are more durable, but the weight is greater, which is sometimes injurious to the collar and the masonry to which it is attached, requiring more repairs than lighter gates.

The frames or stiles of gates should be at least 5 inches in thickness more than the rails, and the joint covered by a fillet, as well as the edge of the planks, which are affixed perpendicularly to the rails, and mortised into the stiles, increasing the strength of the rails and the framework by their greater thickness. Braces are also introduced between the rails, which aid materially in strengthening them, and by their inclined position transfer the stress to the hanging-post.

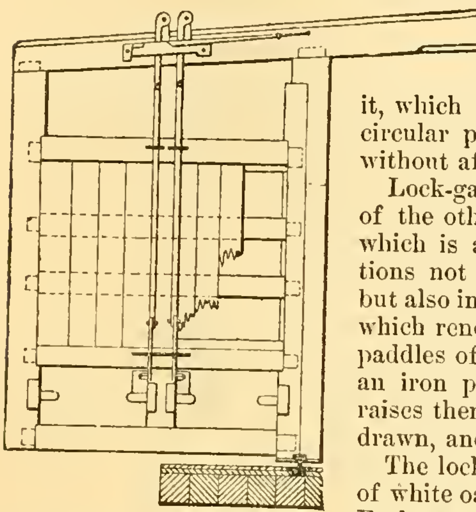
Great gates should always have a line of braces placed diagonally, and making an angle with the lower rail; all the braces above should have the same effect, and consequently the same inclination; those below resting on the lower rail tend to depress it, and, even when properly framed and pinned into the rails, their inclination toward the hanging-post renders them insufficient to sustain the lower rail; but they may be made useful by giving them an inclination in a contrary direction, and uniting them by pins to the rails.

Instead of inclining the braces below the diagonals on the side of the strutting-post, a bar of iron is sometimes placed diagonally from the collar to the lower end of the strutting-post, which is an excellent contrivance; or the planks may be placed diagonally, inclining them from the side of the hanging-post, and crossing them solidly, especially that of the diagonal above the hanging-post, and at the extremity of the lower cross-piece; or instead of a plank, a piece may be let in in an opposite direction to the cross-pieces, which must not be mortised into, or very little, that it may not be in any way weakened; this piece united carefully to the lower cross-piece would tie it to the post, and give more solidity to the framework; the diagonal position of the planks gives them more strength to resist the pressure. There is a little loss of material, but, on the other hand, plank of different kinds may be used after cutting out the knotty or defective portions.

Gates are opened by means of large timbers fixed above the posts, forming a counterpoise to the gate, and preventing it from grinding the collars and racking the framework; for this purpose the tail of the balance-beam must be very large. Trees are sometimes used with their butt-ends not cut off, to which it is easy to add any additional weight. The hanging-posts often allow much water to be

lost, in consequence of being obliged to give them sufficient play, and this could scarcely be prevented if the pivot had not a little motion, and the collar fitted exactly; but the weight of water occasions the gate to unite by pressing it considerably against the hanging-post; still, as this is cut circularly, it only leans against a small portion of its surface, and the water easily passes, notwithstanding the great pressure. To remedy these defects, the posts should be partly cut in a circular form, and partly beveled; the latter leaning along its whole length upon the rebate made to receive it, which having a corresponding bevel interrupts any filtration; the circular part should not touch the masonry, but have sufficient play without affecting the ease of the motion.

651.



Lock-gates measuring 8 feet from the centre of one heel-post to that of the other are in some canals on a segment of a circle, the chord of which is about the sixth of the span, or a little more; these proportions not only allow of the gates being smaller, lighter, and stronger, but also increase the pressure of the heel-post against the hollow quoins, which renders them quite water-tight. Where canals are narrow, the paddles of both the upper and lower gates are usually kept open by an iron pin inserted between the teeth of a rack and pinion which raises them; when the paddle is required to be shut, the pin is withdrawn, and the paddle falls by its own weight.

The lock-gates, Fig. 651, of the above-described lock are constructed of white oak, planed; the cross-bars framed into the heel and toe posts. Each tenon is 7 inches long, and the width equal to the thickness of bar, and secured with wrought-iron T's. The heel and toe posts are framed into the balance-beam by double tenons, and secured by a wrought-iron strap and balance-rod, from the top of the beam to the under side of the upper bar. The lower end of the heel-posts are banded with wrought-iron bands. The pivots, sockets, boxes, and journals are of the best quality chilled cast-iron. The gates are planked with seasoned 2-inch white-pine plank, secured by 6-inch pressed spikes.

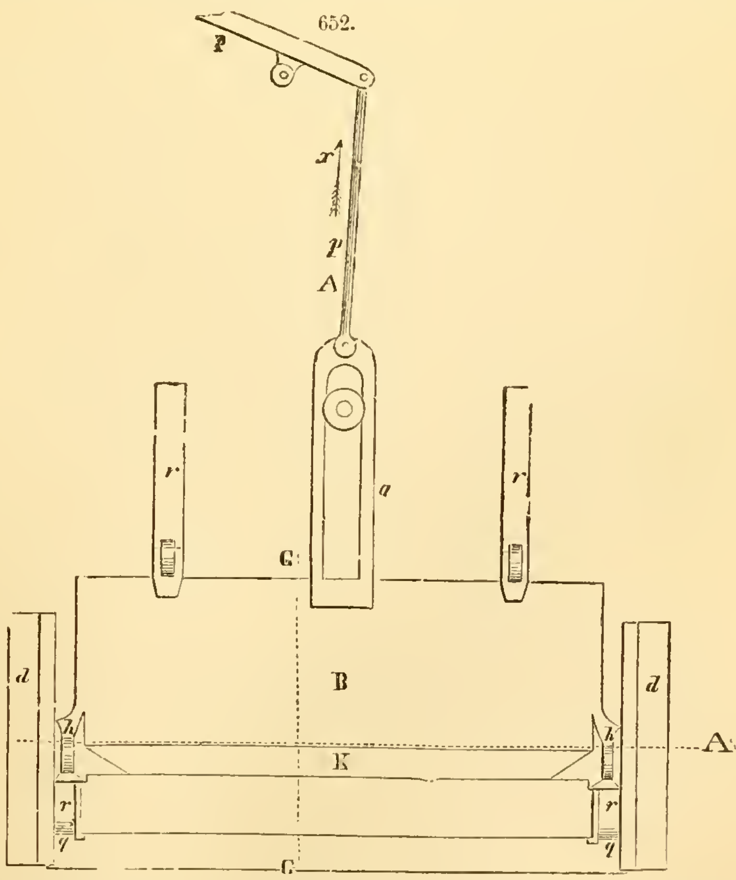
Hollow quoins, or upright circular grooves, are formed in the side walls, at the ends of the timber sills, serving as the hinge for the gates; the upright post that turns within them is called the heel of the gate, and the other the head. The former are retained in their position by a gudgeon or pivot turning in a cup let into the foundation stones for the purpose; sometimes the pivot is fixed, and the cup revolves upon it. The upper part of the post is retained by an iron ring or strap let into the side wall, and made very secure; the hollow quoins should be worked with great attention; they are usually of stone or brick, though cast-iron has been found well suited for the purpose.

The angle to be given to double lock-gates has long occupied the attention of engineers, but the strongest position may be taken when the angle at the base is 35° 16′ nearly, and the sally of the gate is seven-twentieths, or a trifle more than one-third, of the breadth of the lock.

*Valves.* — Some lock-gates have their paddles, or valves, made to open and shut by the movement of a lever, the lower end of which, being loaded, keeps it always over the aperture in the lower part of the gate; when it is required to be moved, the upper part or handle of the lever is pulled back, and the water, forcing its passage through, keeps it open until its weight overcomes the power, and it is balanced back into its original position.

The crank and pinion, working in a toothed rack, are now generally applied to raise the paddle.

652.



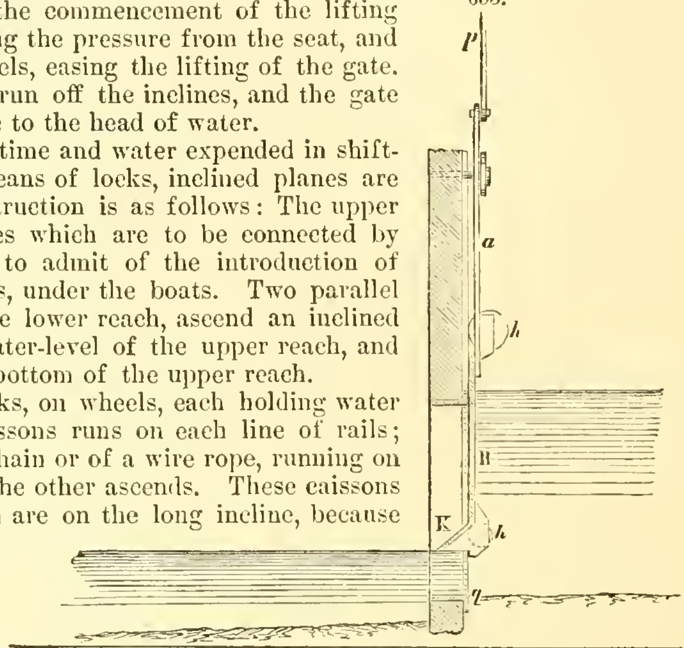

Screws are sometimes used for this purpose, formed of wood, sliding up and down in a rebated frame, fixed in the stone mouth of the conduit or paddle-hole. The lateral pressure of the water causes it to adhere closely to the frame, so that it is not only necessary to make it run with the grain of the wood, but also to have considerable power to move it; this is occasionally effected by means of a long iron lever, with an eye at one end that spans the square end of the screw, and allows a sufficient force to be applied to raise

the paddle. There are several applications of the screw, one of which, as used at the gates of Dunkirk, is very simple, and was for a long time adopted throughout Europe. To overcome the hydrostatic pressure and friction, at the mouth of the paddle-hole was a horizontal circular opening, within which was inserted an open cylinder of wood or iron ground to fit it, which could be raised by a lever; the waste water of the canal could then escape over the upper lip of the cylinder, and afterward pass out by the paddle-holes.

Figs. 652 and 653 represent an arrangement for the valves or sluices of a lock-gate. Fig. 652 is an elevation; Fig. 653, a vertical section through $G$ $G$.

The object of this arrangement is that, while the gate is kept close and tight by the pressure of the water forcing it against its seat, the effort of lifting the gate shall at the same time relieve the seat from the pressure of the water; and this is effected by means of friction-rollers $h$ $h$, which, immediately upon the commencement of the lifting of the gate, act as short inclines, thus taking the pressure from the seat, and throwing it upon the friction-rollers or wheels, easing the lifting of the gate. When the gate is closed, the wheels have run off the inclines, and the gate bears against its seat with the pressure due to the head of water.

653.




*Inclined Planes on Canals.*—To save the time and water expended in shifting boats from one level to another by means of locks, inclined planes are used on some canals. Their general construction is as follows: The upper and lower reach of the canal, at the places which are to be connected by inclined planes, are deepened sufficiently to admit of the introduction of water-tight iron caissons, or movable tanks, under the boats. Two parallel lines of rails start from the bottom of the lower reach, ascend an inclined plane up to a summit a little above the water-level of the upper reach, and then descend a short inclined plane to the bottom of the upper reach.

There are two caissons, or movable tanks, on wheels, each holding water enough to float a boat. One of these caissons runs on each line of rails; and they are so connected, by means of a chain or of a wire rope, running on movable pulleys, that when one descends the other ascends. These caissons balance each other at all times when both are on the long incline, because the boats, light or heavy, which they contain, displace exactly their own weight of water. There is a short period when both caissons are in the act of coming out of the water, one at the upper and the other at the lower reach, when the balance is not maintained; and, in order to supply the power required at that time, and to overcome friction, a steam-engine drives the main pulley, as in the case of fixed-engine planes on railways. On some canals vertical lifts with caissons are used instead of inclined planes.

*Water-supply.*—With regard to the supply of water necessary for a canal, or for a level of canal, it embraces the quantity required for the service of the navigation, that is, the number of times the chambers of the locks will require to be used in the passage of boats, and the losses arising from evaporation, from leakage through the soil and through the lock-gates, the necessary first fillings of the levels and the chance of accidents or breaches, and the emptying of the levels for repairs. In estimating the quantity expended for the service of navigation, the problem is simple, knowing the capacity, form, and number of locks, the size of boats, and the contemplated amount of traffic. With regard to the other losses it must be largely a matter of conjecture. From experiments made by Mr. J. B. Jervis on the Erie Canal, the total loss from evaporation, filtration, and leakage through the gates is about 100 cubic feet per minute for each mile. Having determined the amount of water required, the source of the supply must be gauged; and if the minimum flow of the stream be not sufficient, reservoirs must be constructed to equalize the supply.

The quantities of water discharged from the upper pond at a lock or flight of locks, under various circumstances, are shown in the tables on the next page. $L$ denotes a lockful of water—that is, the volume contained in the lock-chamber, between the upper and lower water-levels; $B$, the volume displaced by a boat. The sign $-$ prefixed to a quantity of water denotes that it is displaced *from the lock into the upper pond.* The letters $n$ and $m$ stand for a given number of boats or locks, and are used simply for the purpose of generalization. Thus a "train of $n$ boats" may mean a train of 2, 3, 4, 5, or as many boats as are to be considered; and the same number which $n$ represents is applied in the formulæ under "Water discharged." Similarly, a "flight of $m$ locks" means a flight of 2, 3, 4, 5, etc., locks.

From these calculations, it appears that single locks are more favorable to economy of water than flights of locks; that at a single lock single boats ascending and descending alternately cause less expenditure of water than equal numbers of boats in trains; and that, on the other hand, at a flight of locks, boats in trains cause less expenditure of water than equal numbers of boats ascending and descending alternately.

For this reason, when a long flight of locks is unavoidable, it is usual to make it double; that is, to have two similar flights side by side—using one exclusively for ascending boats and the other exclusively for descending boats.

Water may be saved at flights of locks by aid of side-ponds (sometimes called "lateral reservoirs"). The use of a side-pond is to keep for future use a certain portion of the water discharged from a lock, when the locks below it in the flight are full, which water would otherwise be wholly discharged into the lower reach. Let $a$ be the horizontal area of a lock-chamber, $A$ that of its side-pond; then the volume of water so saved is $L\ A \div (A + a)$.

*Table showing Quantities of Water discharged from the Upper Pond at a Lock.*

| SINGLE LOCK. | Lock found | Water discharged. | Lock left |
|---|---|---|---|
| One boat descending | empty | $L - B$ | empty. |
| " " | full | $- B$ | |
| One boat ascending | empty or full | $L + B$ | full. |
| Two $n$ boats, descending and ascending alternately | descending full<br>ascending empty | $n L$ | descending empty.<br>ascending full. |
| Train of $n$ boats descending | empty | $n L - n B$ | empty. |
| " " " | full | $(n - 1) L - n B$ | |
| Train of $n$ boats ascending | empty or full | $n L + n B$ | full. |
| Two trains, each of $n$ boats, the first descending, the second ascending | full | $(2 n - 1) L$ | full. |

*Quantities discharged at a Flight of Locks.*

| FLIGHT OF $m$ LOCKS. | Locks found | Water discharged. | Lock left |
|---|---|---|---|
| One boat descending | empty | $L - B$ | empty. |
| " " | full | $- B$ | |
| One boat ascending | empty | $m L + B$ | full. |
| " " | full | $L + B$ | |
| Two ($n$) boats, descending and ascending alternately | descending full<br>ascending empty | $m n L$ | descending empty.<br>ascending full. |
| Train of $n$ boats descending | empty | $n L - n B$ | empty. |
| " " " | full | $(n - 1) L - n B$ | |
| " " ascending | empty | $(m + n - 1) L + n B$ | full. |
| " " " | full | $n L + n B$ | |
| Two trains, each of $n$ boats, the first descending, the second ascending | full | $(m + 2 n - 2) L$ | full. |

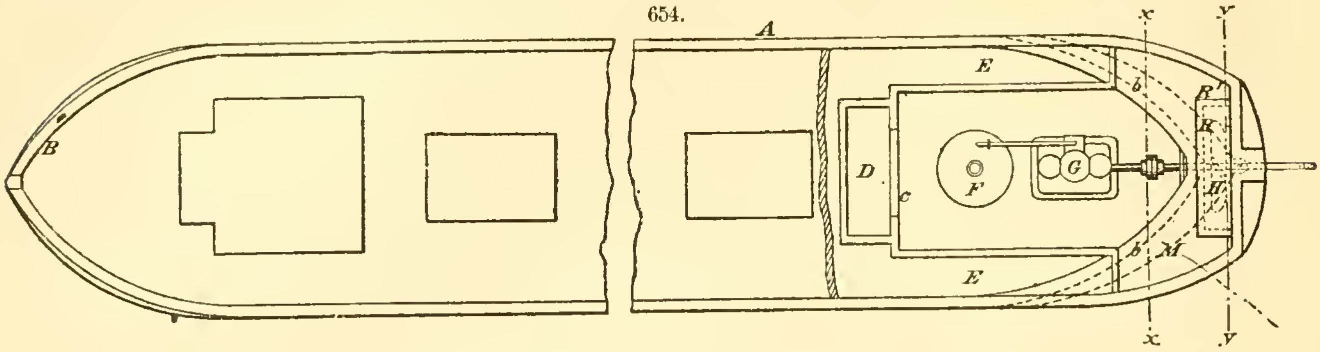
*The least length that can be allowed between the locks* should be such that 12 inches of depth, over and above what a loaded boat will draw, will only lower the water 6 inches without the navigation being interrupted; and if it be required to draw the contents of each lock from the interval above, the distance for the locks must be so regulated that the quantity of water expended by one should not lower that of the upper interval more than 6 inches at most: thus the distance should be greater in proportion to the contents of the chambers of the locks and the width of the canal; that is to say, when the chambers are large and the canal is narrow, the distance between the locks should be greater. Chambers 110 feet in length between the gates, by 17 feet in width, contain 1,870 superficial feet; therefore, 11,843 cubic feet when the fall is 6 feet 4 inches, 15,859 cubic feet when it is 8 feet 6 inches, and 19,635 cubic feet when 10 feet 6 inches. If the canal be 48 feet in width at 3 feet below the ordinary level of the water, the length of the interval should be 446 feet, in order that the expenditure of locks of 6 feet 4 inches of fall should not lower the water more than 6 inches; this length should be 607 feet when the locks are 8 feet 6 inches of fall, and 755 feet when they are 10 feet 6 inches: the distance then between the lower gate of one lock and the upper gate of the other should be always about 624 feet for ordinary canals. If two locks of 8 feet 6 inches fall were only distant 160 feet, the water drawn from the interval, for the purpose of mounting the boat, would lower it nearly 26 inches, and there would not remain sufficient to keep it afloat; consequently, it would be necessary to draw a lockful from the upper interval, and then a second, to cause it to rise, while only one would be required if the locks were at a sufficient distance.

This example will show the inconvenience of having locks too near each other, which is still further increased when they are contiguous. It frequently happens that several boats arrive together in the same interval, particularly where the boatmen stop or sleep; and that no water may be lost, the interval where they stop should be sufficiently long to admit more than one. If circumstances will not permit this, a greater width must be given, that the lockful which the rising boats draw from the interval may not cause the water to lower so considerably as to prevent their floating, or the descending boats force in such a quantity as to make it run over the gates. If the interval has only the ordinary width of 48 feet, it should be 6,398 feet in length, so that ten rising boats could stop, if none were descending at the same time; otherwise a part of the water must be drawn from the other intervals to keep them afloat. If there were as many ascending as descending boats, this need not be so great; but this observation proves that, in forming a canal, it is necessary to have basins at those situations where boats are required to stop any length of time.

*Locomotion on Canals.*—In early times boats were drawn or pushed along by servants or slaves. In civilized countries horses and mules have been chiefly used. In recent years many attempts have been made to use steam-power by driving the boat like a propeller. The most successful boat of this kind was invented by Mr. William Baxter, of Newark, N. J., and competed for the prize of $100,000 offered by the State of New York in 1871 for an acceptable mode of applying steam for propelling canal-boats on the canals—plans involving what is called the Belgian system being excluded. This boat, Figs. 654 to 657, on her first trip in September, 1872, with a cargo of 201 tons, made an average speed of 3.38 miles per hour, expending on an average 31.04 lbs. coal per boat-mile. The power expended appeared to vary from about 23 to about 33 horses, and the coal consumption was about $3\frac{1}{3}$ lbs. per horse-power per hour. The apparent slip of the screw was found to be from $12\frac{1}{2}$ to 33 per cent., while the actual slip varied from $23\frac{1}{2}$ to 25 per cent.

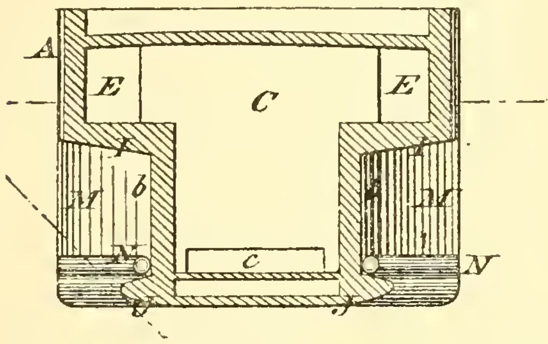
The Belgian system has been quite extensively used in some European countries. It consists of a cable which passes from one end of the canal to the other, and is sunk in it. It is wound around a wheel which is at one end of the boat. Steam-power is applied to turn the wheel; and as the friction

654.




of the rope on the wheel prevents it from slipping, it will take up the cable on one side of the wheel and let it out on the other, and thus draw the boat along. One of the objections to this plan is that it

655.

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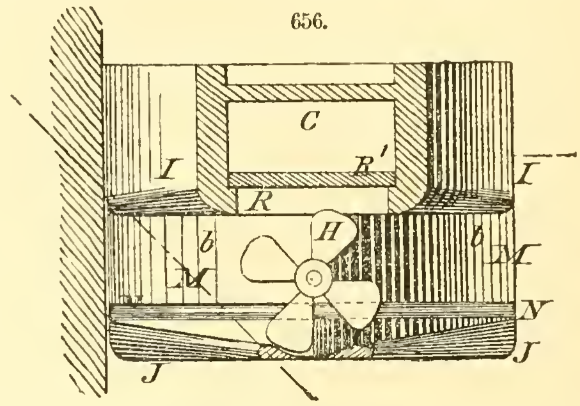
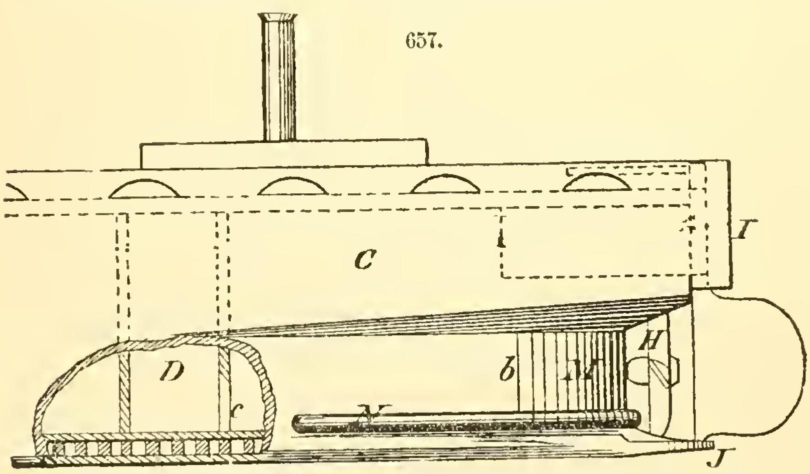



requires a large amount of slack-cable to accommodate a large traffic, and every boat must draw in all the slack every time it passes over the canal.

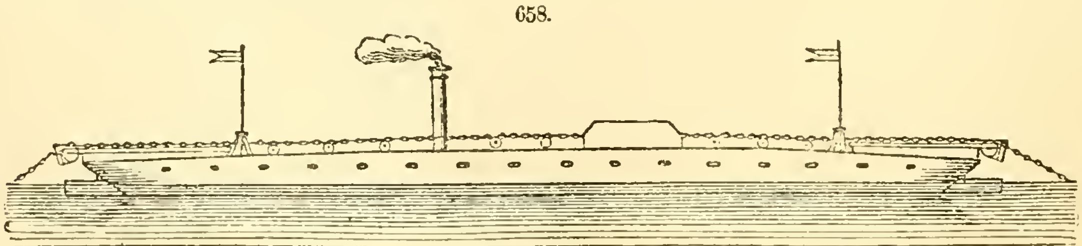
The machinery of a chain-towing steamer, the most perfect type of which, as worked on the Elbe, is given in Fig. 658, consists of a pair of drums worked by gearing from engines of 80 horse-power. At each extremity it is furnished with long outriggers, pivoted at one end, the other projecting beyond the ends of the vessel, formed of double T-irons, holding a series of loose pulleys and a pair of vertical guides. Between the drums and the outriggers there are 16 or more horizontal pulleys placed in a gutter about 10 inches wide by 8 inches deep, and four or more vertical guides for supporting and guiding the chain.

657.




The chain is taken on at the stem, and dragged between and over the pulleys and guides to the drums, which are massive castings of chilled cast-iron or cast-steel. The peripheries of these are divided into grooves to prevent the triple rounds of chain in their passage over the drums from

658.



getting entangled together. Thence the chain runs along the gutter supported by the loose pulleys, and over the outrigger, where it is paid back again into the water. The objects of the outriggers are: first, to allow the chain to come on or to run off the steamer without cutting into the edges of the deck or fenders, and to clear the rudders; and secondly, in passing round curves, to allow of its being taken up and run out at an angle to the line of the steamer's movement. In front and astern of the drums there are wells for containing the slack chain, should there, from a surplus quantity of

chain, be no strain astern of the drums to haul the chain from off the vessel. This slack remains until the tension behind draws it away again into the river.

The chain used on the Elbe is composed of 1-inch, and in some places $1\frac{1}{16}$-inch iron.

Wire-cable-towing steamers, such as are in use in various parts of Germany, have in the centre or mid-line, raised to a sufficient height, two metal drums, the periphery or outer circumference of which is divided into five grooves. These drums are made conical, so that the length of each groove measured round the circumference of the drum is different, greater or less than the rest, to correspond with the difference of the strains developed by the tension of the cable; or, in other words, by the power transmitted from the engines to the drums, and from the drums to the wire cable. These drums, revolving upon strong shafts, are worked by double sets of gearing from the engines, for fast or slow motion; but that their speeds, which vary under different strains, may correspond and be regulated exactly, they are coupled together by means of the three-toothed wheels, one of which is a friction-wheel. A loose pulley raised or lowered by a lever is placed between the drums below the lower line of their circumference, for the purpose of insuring the adhesion of the cable to the drums when necessary.

The shafts carrying the drums also support the transmission-pulleys which, by means of two endless wire cables held at the vessel's extremities by pulleys, transmit the necessary movement from the engine to the taking-in and paying-out apparatus termed a "truck." This is employed for the purpose of guiding the cable with a certain tension on to the drums, and of relaying it from the steamer as it leaves the drums. It comprises a strong framing of angle-iron, and is furnished below with small wheels by means of which it runs on deck, and is held down to rails of proper form bolted to the deck-beams.

The truck is furnished with four horizontal press-rolls, two above and two below, working in pairs on two upright shafts. The lower pair of press-rolls receive and transmit the power from the engines, and the upper pair guide and pay the cable on and draw it off from the drums, and relay it. These press-rolls are cast-iron wheels, carrying at their periphery 60 teeth working on India-rubber rings. These teeth are cast in metal, and their outer faces bear the impress of the strands of the cable, so that the latter may receive or transmit power without friction or injury to either. The truck carries in front two large hollow vertical drums for guiding the cable during the passage of curves, between the press-rolls, and is furnished above and below with several small horizontal pulleys for supporting the cable horizontally.

The engines being started, the drums and the transmission-pulleys begin to revolve; and, the transmission-cables driving the lower press-rolls of the forward and after truck, the cable is paid on to and drawn off from the drums at the requisite tension by the revolution of the upper press-rolls. As the cable passes from between the upper press-rolls of the fore-truck, it runs straight on to the first groove of the forward drum. The cable revolves round the drums, and then runs to the after-truck, where it passes between the upper press-rolls, and is paid out over the stern of the steamer.

The wire cable generally used is seven-eighths of an inch in diameter. Messrs. Meyer and Wernigh, the inventors of the above-described wire-cable-towing steamers, give as the results of their dynamometrical trials the following

*Table of Working Capabilities of Wire-cable-towing Steamers, in Still Water, at different Speeds, with Barges of different Draughts, empty or laden.*

<table>
<tr><td></td><td colspan="3">DIMENSIONS.</td></tr>
<tr><td>Total resistance to tractions of steamer and train in lbs ........ $= P$.<br>Speed in feet per second ........ $= V$.<br>Immersed section ........ $= F$.<br>Resistance of vessels in lbs ........ $= W$.<br>$$HP = \frac{P \times V}{550}.$$</td><td colspan="3">Empty barge.....$L = 131' 10''$, $B = 14' 11''$, $D = 1' 6''$.<br>" lighter....$L = 131' 10''$, $B = 14' 11''$, $D = 8''$.<br>Laden barge[1].....$L = 131' 10''$, $B = 14' 11''$, $D = 3' 3''$.<br>" lighter[2]....$L = 131' 10''$, $B = 14' 11''$, $D = 3' 3''$.<br>[1] Load or cargo in cwts ........ 1,571<br>[2] " " " ........ 2,455</td></tr>
<tr><td rowspan="2">CONDITIONS.</td><td colspan="3">MAXIMUM EFFECT IN NUMBER OF BARGES TOWED.</td></tr>
<tr><td>50 H. P. Engines: $V = 3' 3''$ per second, or 2.2 miles per hour, with $P = 13$ cwts.</td><td>25 H. P. Engines: $V = 6' 6''$ per second, or 4.4 miles per hour, with $P = 18$ cwts</td><td>25 H. P. Engines: $V = 3' 3''$ per second, or 2.2 miles per hour, with $P = 36$ cwts.</td></tr>
<tr><td>Empty barge.............$F = 21.6$ sq. ft., $W = 66$ lbs.</td><td>125</td><td>...</td><td>62</td></tr>
<tr><td>" " .............$F = 21.6$ " $W = 286$ "</td><td>...</td><td>7</td><td>...</td></tr>
<tr><td>Empty lighter.............$F = 9.6$ " $W = 29$ "</td><td>287</td><td>...</td><td>144</td></tr>
<tr><td>" " .............$F = 9.6$ " $W = 121$ "</td><td>...</td><td>17</td><td>...</td></tr>
<tr><td>Laden barge.............$F = 48.4$ " $W = 150$ "</td><td>55</td><td>...</td><td>27</td></tr>
<tr><td>" lighter.............$F = 48.4$ " $W = 605$ "</td><td>...</td><td>8</td><td>...</td></tr>
</table>

In this table regard is had to the coefficient (.3) of the ship's resistance, upon which these trials were carried out.

*Works for Reference.*—"Architecture Hydraulique," Belidor, Paris, 1737–'53; "Des Canaux de Navigation," Lalande, Paris, 1778; "A Treatise on the Improvement of Canal Navigation," Fulton, 1796; "On Canal Navigation," Chapman, 1797; "Canal de Languedoc," Andréossy, Paris, 1804; "Traité d'Hydraulique," Ducrest, Paris, 1809; "Œuvres," Gauthey, vol. iii., Paris, 1816; "Œuvres," Cordier, Paris and Lille, 1819–'28; "Des Canaux Navigables," De Pommeuse, Paris, 1822; "His-

toire de la Navigation Intérieure de la France," Dutens, Paris, 1829; "Précis Historique, etc., des Canaux de Belgique," De Rive, Brussels, 1835; "De la Dépense et du Produit des Canaux et des Chemins de Fer," Pillet-Will, Paris, 1837; "Traité d'Hydraulique," D'Aubuisson de Voisins, Strasbourg, 1840; "Cours de Construction des Canaux," Minard, Paris, 1841; "Percement de l'Isthme de Suez," De Lesseps, Paris, 1855; "Report on the Gauges Canal," Cautley, 1860; "Handleidung tot de Kennis der Waterbouwkunde," Buysing, Buda, 1864; "Recherches Hydrauliques," Darcy, Paris, 1865–'6; "On Rivers and Torrents, aud on Canals," Frisi, translated by Garstin, 1868; "Uferschälungen und Sheffarts Canäle," Hagen, Berlin, 1871; "Report on the North Sea Canal and on the Improvement of Navigation from Rotterdam to the Sea," Barnard ("Professional Papers, Corps of Engineers U. S. A.," No. 22), Washington, 1873; "Canal and River Engineering," 2d ed., Stevenson, Edinburgh, 1872; "Manuel de l'Ingénieur des Ponts et Chausseés," Debauve, fascicule 15, Paris, 1873; "Hydraulic Manual and Statistics," L. D'A. Jackson, London, 1875; "Hydraulic Tables, Coefficients, and Formulæ," Neville, London, 1875; "Elements of Practical Hydraulics," Downing, London, 1875; "The New Formula for Mean Velocity of Discharges of Rivers and Canals," Kutter, translated by Jackson, London, 1876; Reports of U. S. Secretary of the Navy for 1868 to 1876 (proposed canal across the Isthmus of Darien). See also numerous papers in *Annales des Ponts et Chaussées*, *Engineering*, "Tracts" by Lombardini of Florence, *Engineer*, *Van Nostrand's Eclectic Engineering Magazine*; also the works of Rankine, Moseley, Weisbach, Mahan, and others on Civil Engineering.
C. B. G.

CANDLE, JABLOCHKOFF'S. See Electric Light.

CANNON. See Ordnance.

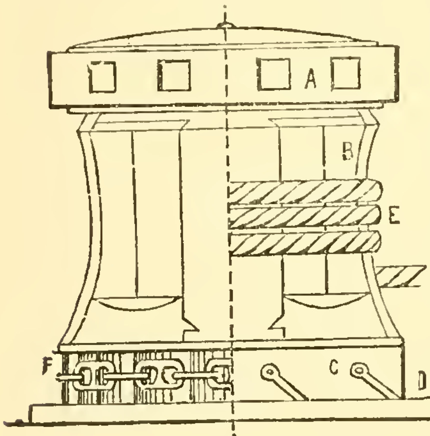
CAOUTCHOUC. See India-Rubber Working Machinery.

CAPPADINE. The waste taken from the cocoon after the silk has been reeled off.

CAPPOT. A covered crucible used in glass-making.

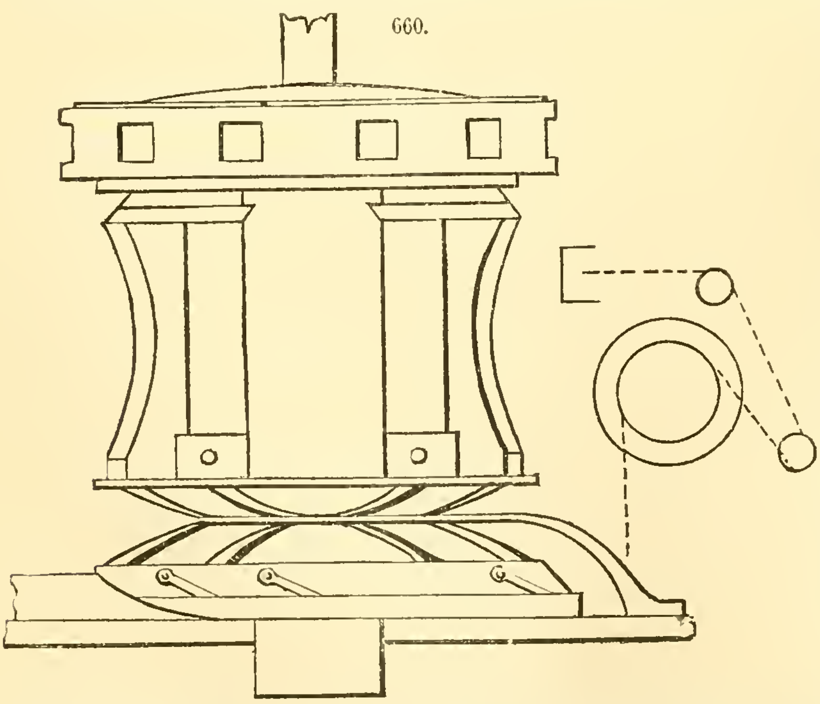
CAPSTAN. A modification of the mechanical power known as the wheel and axle, consisting of a vertical drum about which the chain or rope applied to the weight to be lifted is wound, this drum being rotated by levers inserted in suitable apertures in its upper portion. The levers are called capstan-bars, and when in place radiate from the capstan-head like the spokes of a wheel. On board ship, where the capstan is used for lifting the anchor, several men stand side by side along each bar and push on the same, walking continuously around, and so applying a steady pull on the chain. In this respect the capstan differs from the windlass, the drum of which is placed horizontally and turned by bars which are arranged in connection with ratchet-wheels, so that the pull on the chain ceases as each bar, on arriving at the end of its course, is thrown back to get a fresh purchase on the barrel or drum. The capstan is superior to the windlass in point of expedition, but the men exert their strength more efficiently on the windlass than at the capstan, since in the latter case they are compelled to push horizontally, when they exert a pressure only of about 35 lbs., whereas in the windlass the weight of the body, averaging about four times this strain, is applied to the end of the lever.

659.



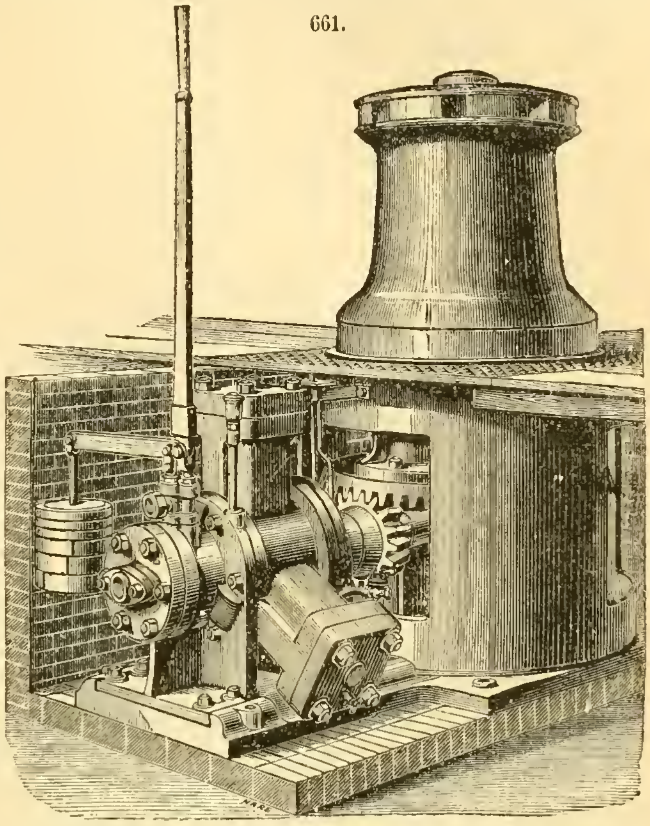

Capstans on board ships are either single or double, according as there are one or two barrels upon the same spindle. The double capstan is revolved by two sets of men, the barrels being respectively located on different decks. The common capstan is represented on the right of the dotted line in Fig. 659. Its parts are the spindle on which the barrel turns, the drum-head *A*, whelps *B*, pawl-head *C*, and pawl-rim *D*. The barrel of the capstan is covered by the whelps, of which there are usually six, which are bolted to the barrel and further retained by the drum-head, which extends down over them for about an inch. The object of the pawls is to prevent the capstan from flying back when the strain ceases. They are fastened to the pawl-head, and fall into small cells in the pawl-rim. Their disposition is usually such that the capstan cannot recoil for more than half the length of one of the cells before being checked. When this form of capstan is used on board ship, the anchor-chain is not brought directly to it, but the strain is applied to the latter

660.



through the medium of a *messenger*, *E*. This consists of a heavy endless rope which is wound several times around the capstan, and passes over a roller or sheave in the bow of the vessel. The chain, which extends aft parallel to the messenger, is secured to the rearwardly moving portion by *nippers*, which are grummets of soft rope wound around both chain and messenger, and held by a lever which is removed, and the chain freed, as the latter reaches the scuttle in the deck, down which it passes to the lockers below. Capstans have been constructed with wheelwork between the spindle and barrel, the former making 3 turns and the latter 1, revolving in opposite directions, so that the power is augmented as 3 to 1.

661.



In more modern forms of capstans the chain is taken directly to the barrel without the intervention of a messenger. A capstan of this description is represented on the left of Fig. 659. This is provided with a sprocket-wheel *F*, which engages the links of the chain passed around. A better form, and that most commonly used on board of war-vessels, is represented in Fig. 660. Here the chain is led around vertical rollers, as shown in the diagram on the right, and then around the lower ribbed portion of the capstan. The construction of this part is such that the chain is very firmly grasped.

Both capstans and windlasses on large steam-vessels are frequently constructed to be operated by steam-power, auxiliary engines being especially arranged for this purpose. Ellington's improved form of hydraulic capstan for use on docks is represented in Fig. 661. Motive-power is supplied by a three-cylinder engine operated by water-pressure, and geared to the capstan as shown. This device has the merits of compactness and great power.

For the theoretical considerations relative to capstans, see *Wheel and Axle*, under STATICS.

CARBON. See DIAMOND.

CARBONIC ACID, as a motor. See GAS-GENERATING MACHINES.

CARBON POINTS. See ELECTRIC LIGHT.

CARDING. See COTTON-SPINNING MACHINERY, and WOOL-SPINNING MACHINERY.

CARILLON. See BELLS.

CARPENTRY. The art of adapting timber to structural purposes. By some authorities it is regarded as a distinct art from joinery, which is commonly defined as the production of fittings for houses, patterns for casting, etc. Most of the work of fashioning timber which formerly required the carpenter's skill is now done by machinery. Rabbeting, grooving, tonguing, mortising, moulding, tenoning, boring, gaining, planing, sawing, and carving are all done by ingenious contrivances far more accurately and more speedily than the same can be accomplished by the best of hand-labor. Thus the distinction between carpentry and joinery is virtually obliterated; or rather the modern carpenter has necessarily become a joiner, his chief duty being the assemblage of parts previously prepared by machines. The present article therefore relates more especially to joinery. The application of the art to pattern-making will be found under PATTERN-MAKING AND MOLDING. The various tools used by carpenters are described under AWL, AXE, BITS AND AUGERS, CALIPERS, CARVING TOOLS, CHISELS, CLAMPS, COMPASSES, DRAWING-KNIFE, GAUGES, GOUGE, GRINDSTONE, HAMMER, LATHE (WOOD-TURNING), LATHE TOOLS, OILSTONE, PLANES, RASP, RULE, SAWS, SCREW-DRIVER, SCRIBING-BLOCK, SPIRIT-LEVEL, SPOKESHAVE, SQUARE, STRAIGHT-EDGE, and VISE. See also DRILLING AND BORING MACHINES, MORTISING AND TENONING MACHINES, PLANING MACHINES (WOOD), SHAPING AND MOULDING MACHINES (WOOD), and STRENGTH OF MATERIALS.

JOINTS AND FASTENINGS.—The following are the principles which should be adhered to in designing joints and fastenings, as laid down by Prof. Rankine:

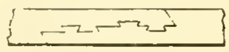
"1. To cut the joints and arrange the fastenings so as to weaken the pieces of timber that they connect as little as possible. 2. To place each abutting surface in a joint as nearly as possible perpendicular to the pressure which it has to transmit. 3. To proportion the area of each surface to the pressure which it has to bear, so that the timber may be safe against injury under the heaviest load which occurs in practice, and to form and fit every pair of such surfaces accurately, in order to distribute the stress uniformly. 4. To proportion the fastenings so that they may be of equal strength with the pieces which they connect. 5. To place the fastenings in each piece of timber so that there shall be sufficient resistance to the giving way of the joint by the fastenings shearing or crushing their way through the timber."

The simplest forms of joints are the best, so that the parts may be fitted with the least possible inconvenience. Double abutments should be avoided, as they are difficult to fit; moreover, when the timber shrinks the whole strain may be thrown upon one of them.

*Scarfs* are so made that the pieces fit into one another, so that the resulting beam is of the

same thickness throughout. The usual method of scarfing bond and wall plates is by cutting about three-fifths through each piece, on the upper face of the one and the under face of the other, about 6 or 8 inches from the end transversely, making what is termed a *kerf;* and longitudinally from the end, from two-fifths down, on the same side, so that the pieces lap together like a half dovetail. Fig. 662 is a scarf.

662.



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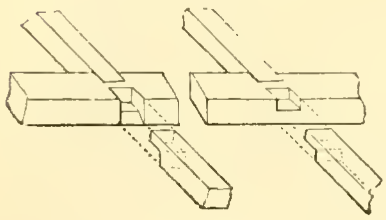

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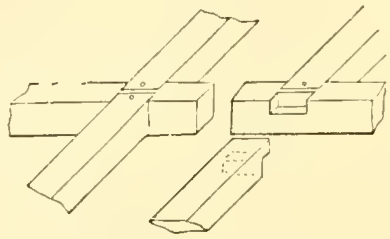

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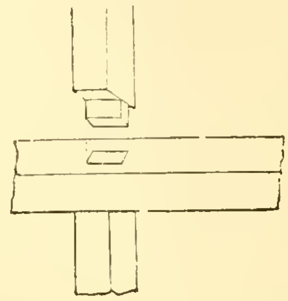


*Notching* is either square or dovetailed, and is made use of for connecting the ends of wall-plates and bond-timbers at the angles, in letting joists down on girders, binders, purlins, or principal rafters.

*Cogging*, or *cocking*, is a species of notch extending on one side, and having a narrow cog alone in the bearing piece, flush with its upper face. It is principally made use of in tailing joists on wall-plates.

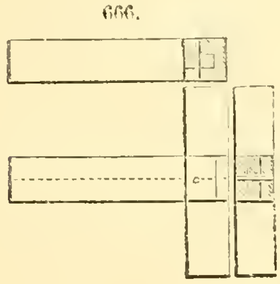
*Pinning* consists in inserting cylindrical pieces of wood or iron through a tenon.

*Wedging* is the insertion of triangular prisms, whose converging sides are under an extremely acute angle, into or by the end of a tenon, to make it fill the mortise so completely as to prevent its being withdrawn.

*Tenon and mortise* of the most simple kind is shown in Fig. 666, in which the two timbers united are at right angles with each other. The tenon is on that which appears horizontal, while the mortise is cut in the upright timber. The tenon is left one-third of the thickness of the timber, as shown in the upper part of the figure.

The greatest strain upon the fibres of a girder is at the upper and lower parts, decreasing gradually towards the middle of the depth, which is the best situation to make the mortise. The form to be given to the tenon requires consideration. Some carpenters introduce it at the lowest part of the girder, which in a great degree destroys its stiffness; being a sixth of the depth, it should be placed at one-third of the depth from the lowest side. Horizontal timbers, intended to bear great weights, should be always notched on their supports, in preference to being framed in between them; and this rule is applicable to inclined timbers, as common rafters and braces. All the pressures to which they are subjected should be brought to act in the direction of their lengths, and the form of the joint should be such as to convey the pressure as much as possible into the axes of the timber. When subjected to a strain, a partial bearing is liable to very serious disadvantages, particularly in bridges.

666.



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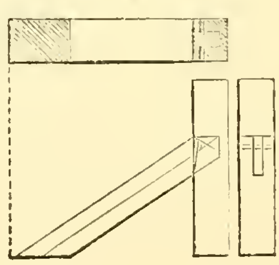

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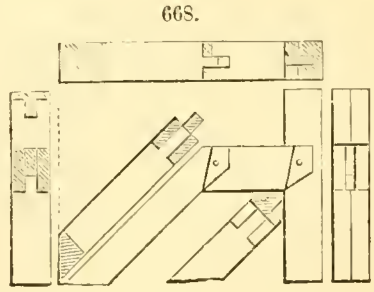


Where the mortise is to be made in the upright timber, and the tenon to be cut on another inclined, as in a brace to a partition, a beveled shoulder, Fig. 668, is cut on the inclined piece, and a sinking made in the upright post to receive it—the pin which secures it in its mortise passing through the tenon.

The beveled shoulder adds greatly to the strength of a mortise and tenon joint, and should never be dispensed with: it renders the junction of the two pieces of timber more exact, and makes the abutments of all the fibres stronger and more capable of resistance.

The common method of effecting such a junction does not occupy so much time or labor, but is not so effective: it is usual to drive one or two wooden pins through holes bored for the purpose at right angles through the timber in which the mortise is made, as well as through that which has the tenon.

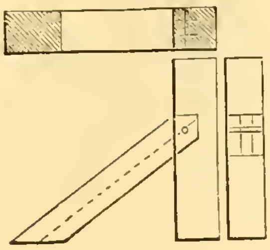
Boring the hole for the pin requires to be nicely performed, in order that it may draw the tenon tight into the mortise prepared to receive it, and make the shoulder-butt close into the joint, without running the risk of tearing out a portion of the tenon beyond the pin. Square holes and square pins are preferred to round, as they bring more of the wood into action, and there is less liability to split.

*Foxtail wedging*, adopted by ship-carpenters, is made with long wooden bolts, which do not pass completely through the timbers, but take a very fast hold: they are subject to be crippled in drawing, if they are too nicely fitted: this is remedied by placing a thin wedge into the hole previous to the

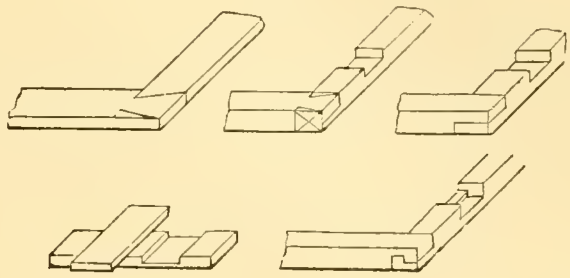
insertion of the wooden bolt, which, when driven, is split by the wedge, and thus squeezed tight to the sides of the hole.

*Bond-timbers and wall-plates* require to be carefully notched together at every angle and return, and scarfed at every longitudinal joint.

669.

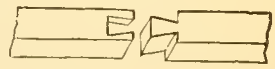


670.



To make a good tie-joint requires great attention on the part of the carpenter; and, for uniting wall-plates, the dovetail joint, Fig. 671, is sometimes adopted. If the effects that shrinking may produce be taken into consideration, the more usual system of halving, Fig. 670, is decidedly preferable. Whenever this joint is employed, a stout pin of tough oak, or an iron bolt, should be driven through to render it secure; and, where there is the slightest tendency for one piece to slide from the other, iron straps must be used.

671.

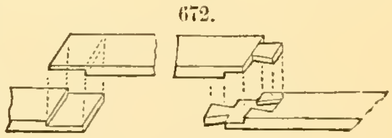


*Timbers which are laid upon the plates*, and intended to act as ties, should be cut with a dovetail and let into the timber it is to secure. Generally, where they cross at right angles, *halving* or cutting away the moiety of each is adopted, and one is let into the channel cut in the other.

For joining two pieces of timber together, *notching* is the most common and simple method; for, when four angles are to be formed, the surfaces of one piece are both parallel and perpendicular to those of the other. A notch may be cut out of one piece (Fig. 671) the breadth of the other, which may be let down on the first; or the two pieces may be both notched to each other, and then secured by an oak pin: this is the best practice when each of the timbers is equally exposed to a strain in any direction. When one piece has to support the other transversely, the upper may have a notch cut across it, to the breadth of two-thirds the thickness of the one below, which must also have a similar notch cut out on each upper edge, leaving two-thirds of the breadth of the middle entire, by which means the strength of the supporting or lower piece is less diminished than if a notch of less depth were cut the whole breadth. Such joints are particularly adapted for purlins, when let down upon the principal rafters.

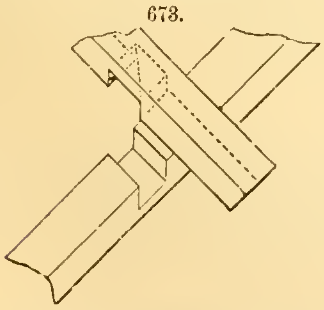
*Lapping* is performed in a variety of ways—either by simply halving the end of each timber, or by halving and dovetailing, as in Fig. 672. In the latter case, the timbers act as a tie, and cannot be readily pulled asunder.

672.



In these joints the greatest attention is required to make the several parts abut completely on each other, as the least play or liability to motion at once destroys their efficacy. The butting joints, being slightly tapered to one side of the beam, require very moderate blows with a hammer to force them into their place: if driven too hard, the parts will be liable to strain, and the abutments to split off. It is better, sometimes, to leave the abutments open, and afterwards drive in a small wedge, which, if made of hard wood and not likely to compress, is an excellent substitute. Iron has been said to injure the fibres of the timber, from its too great hardness; otherwise it is well adapted for the joggles and wedges.

673.



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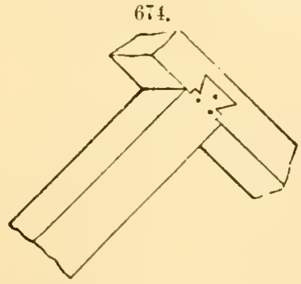
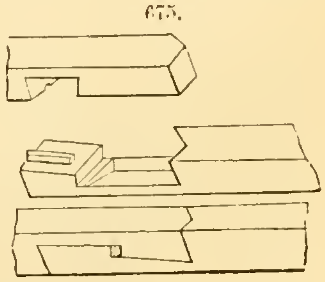
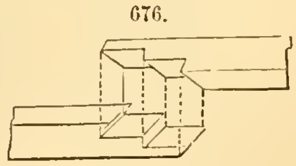


675.



Two pieces of timber may be united in such a manner that they preserve the same breadth and depth throughout, which is of great importance in the construction of beams for bridges or roofs of considerable span. The length to be given to the scarf must depend upon the force that will cause the fibres of the timber to slide upon each other; and that for oak, ash, or elm should be six times the depth of the timber; in fir, twelve times: but where bolts are used so much is not required in either case. The simplest method for uniting the ends of two timbers is by cutting away an equal portion of each, and letting one down upon the other. Fig. 676.

676.

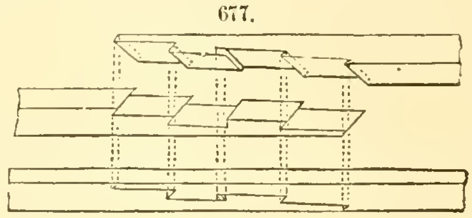


Timbers united together by a number of such cuttings, afterwards united and bolted through or hooped round with iron, are capable of sustaining great resistance: a stirrup-iron at each end

holds the timbers in their places, and one or more bolts are sufficient to prevent their being drawn asunder.

The carpenter frequently exercises great ingenuity in joining timbers of considerable scantling, Fig. 2450; and, by the introduction of iron or small cubes of harder wood into the joints, can prevent their being thrust or drawn out of their position either longitudinally or laterally.

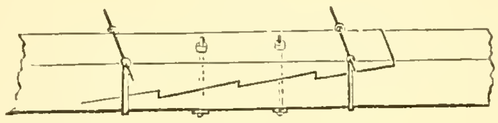
677.



*The scarfing of girders and beams* have a great variety of forms given them, and are sometimes bolted through, at others strapped round with strong hoops of iron, Figs. 676 to 681. Where bolts are dispensed with, it is perfectly clear that the joint cannot have half the strength of an entire piece. Where the stress is longitudinal, two irons put on each side will prevent the scarf that is merely indented from pulling asunder; but such a provision will not maintain the constant horizontal position of the timber.

When a scarf is forced to its bearings by the introduction of keys or wedges driven tight, they sometimes receive an additional strain, and it is often found advisable to omit them, and to bring the joints

678.



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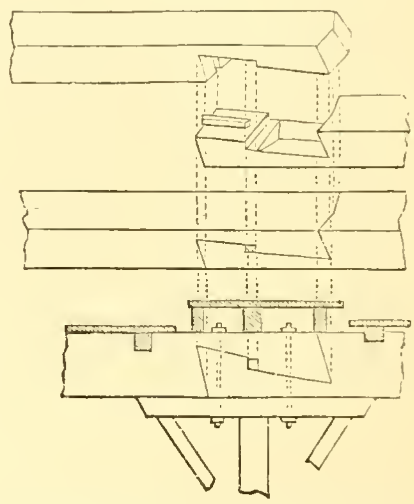
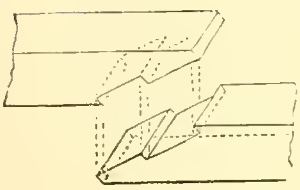


Scarfing.

680.



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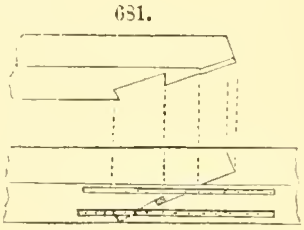


to a bearing by some other means before the bolts are inserted. When keys are made use of, they should be of very hard wood, having a curled grain, which resists the insertion of the fibres opposed to it.

To prevent lateral movement cogging is adopted, in addition to the ordinary method, and a small tenon or cog is left upon a portion of the scarf, which enters into a notch prepared in the piece which is to cover it, as shown in Figs. 675 to 679. Beams intended to resist cross-strains require to be lengthened more frequently than any others, and, from the nature of the strain, a different form of scarf must be made use of from that which is required for a strain in the direction of its length. When timber is subjected to both strains, the cross-strain is that which demands the greatest attention. Where a floor is supported, the scarfing requires to be further secured by iron bolts, made to pass through a longitudinal piece laid to cover the under side of the joint.

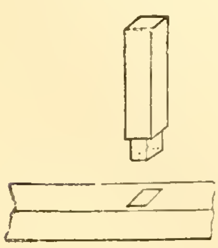
*Bearing-posts*, when used to support the floors of a magazine or warehouse, are generally formed exactly square. Some timber will support, while that of another quality will suspend, the most; therefore, in the selection of story-posts, we must pay attention to these peculiarities. Iron, however, is generally used for these purposes, in consequence of its horizontal sectional area occupying less space than timber of the same strength.

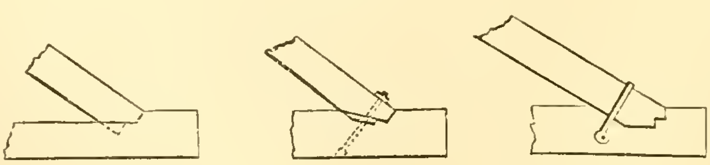
When a tie-beam is mortised through to receive a king or queen post, and it is necessary to provide for the means of holding it up, the tenon should not be pinned through, as it is not advisable to depend entirely on the pins for the support: the tenon should be cut like a half dovetail, or in a sloping direction on one side, and left straight on the other: the mortise-hole should be so cut that the lower end can just pass. When it is in its place, a wooden key or wedge is driven tightly on the straight side, which forces the tenon against one side of the mortise-hole, and prevents it effectually from being drawn out: oak or iron may be added, or an iron strap may be applied.

Tenons may be wedged at the end; but to do this they must be made long enough to pass entirely

682.

Tenons.





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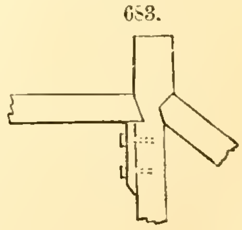


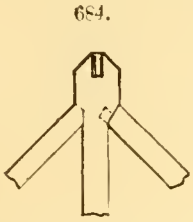
through the mortise: two saw-cuts are then made across it, and the wedges are driven home. The tenon sometimes splits, but not sufficiently to injure its strength. When in machinery it is not practicable to cut the mortise through, the fox-tail wedging is adopted: the tenon is made to fit the mortise

exactly, the wedges are loosely put into the saw-cuts, as before, and the whole is driven to its place When the wedges touch the bottom of the mortise, they cause it to spread, and thus hold the tenon firmly in its place.

Dovetailing in some degree resembles mortising and tenoning, and is more adapted to uniting together the angles of framework. The feet of the rafters require the mortise and tenon to be carefully made, and the thrust is destroyed to a certain extent to obtain greater strength. A portion of the rafter is tenoned into the tie-beam, and another small part is let into the upper part of it: both rafter and tenon are cut at right angles with the inclination of the roof. In Fig. 683, the rafter has two bearing shoulders in its depth, one behind the other, in addition to the tenon which unites them. Struts and braces which are loaded require but little mortising to keep them from sliding out of their places: the more flat their ends can be cut, the more efficient will they be. The shrinking of timbers sometimes occasions them to become loose, particularly where there is not much stress upon them.

King-posts, queens, and principal rafters, which are subject to great strains, should have iron straps or ties when they unite with the tie-beam, as in Figs. 684 to 686; and an iron strap should embrace

684.



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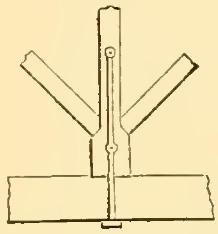

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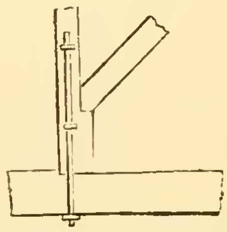


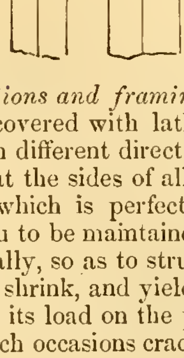
the head of the kings and queens, and unite with the principal rafters, the feet of which, in large buildings, sometimes have their abutment in a cast-iron shoe, which prevents the splitting off the end of the tie-beam.

The ends of king or queen posts may have a screw-bolt passed into them, which allows the nut to be turned at pleasure; and thus the framing may be tightened again when shrinking of the timbers renders it necessary. This, in many instances, is preferable to the iron strap, and keys or screws put in the ordinary way.

Whatever form we adopt for the butting-joint, we must be careful that all parts bear alike; for, in the general compression, the greater surfaces will be less affected and the smaller undergo the greatest change. When all have come to their bearing, they should exhibit an equally close joint; and as large timbers are moved with some difficulty, the joint cannot be often put to the test of trying whether it fits nicely: it must, therefore, be set out with great precision, and worked, with regard to its lines, with exactness. A very small portion of a tie-beam left at the end is sufficient to withstand the horizontal thrust of a principal rafter, and blocks may be used at the ends where the rafters abut to give additional strength.

*Scarfing a timber in a perpendicular direction.*—When the top surface is divided into nine squares, if four are cut down, the other five serve as tenons to enter into as many vacant spaces left in the piece of timber placed upon it, as seen in Fig. 687; or two may be cut away, as in the same figure, to receive a tenon left on the upper piece.

687.



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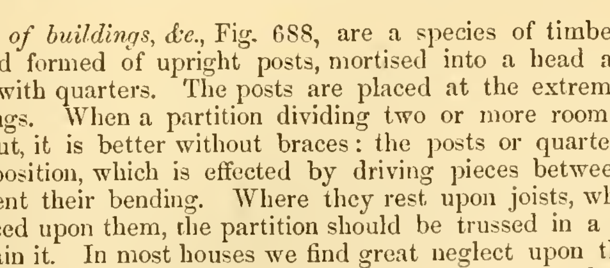


*Partitions and framing for the outside of buildings, &c.*, Fig. 688, are a species of timber walls, usually covered with lath and plaster, and formed of upright posts, mortised into a head and sill, braced in different directions, and filled in with quarters. The posts are placed at the extremities, as well as at the sides of all doors and openings. When a partition dividing two or more rooms has a bearing which is perfectly solid throughout, it is better without braces: the posts or quarters have only then to be maintained in an upright position, which is effected by driving pieces between them horizontally, so as to strut them, and prevent their bending. Where they rest upon joists, which are liable to shrink, and yield to a weight placed upon them, the partition should be trussed in a manner to throw its load on the parts able to sustain it. In most houses we find great neglect upon this subject, which occasions cracking in the cornice, inability to open and shut the doors, and many other inconveniences.

The thickness given to partitions which do not exceed 20 feet in length, is 4 inches. The posts are then 4 inches square, and the other timbers 4 by 3. When they are of greater extent, they should be increased in thickness. When it is required to make a doorway in the middle, the truss may be formed

by the braces, the inclination of which should be at an angle of about 40° with the horizon. When the doors are at the sides, the truss may be formed over the heads. The posts should all be strapped to the truss, and the braces halved into the upright posts.

The weight of a square of quartered partition may be estimated at from 12 cwt. to 18 cwt., and every precaution should be taken to discharge its weight from the floor on which it is placed, to the walls, which are its best points of support. In ancient timber houses, mills, &c., the fronts or external sides are formed of upright posts, placed at a distance equal to their scantling: these are mortised and tenoned into a top and bottom plate, which serves also to carry the floors. The posts at the angles are of a larger scantling; and into these, which form openings for doors and windows, are framed horizontal pieces, which serve for heads and sills. Braces are then introduced, crossing each other, like a St. Andrew's cross. Above the lintholes, and beneath the sills, short quarters or punchions fill in the space, and the whole are mortised, tenoned, and pinned together. The framing should be placed on brickwork, or a wall of masonry, so as to be kept quite clear of the ground.

Floors.—When the bearings are equal, if joists of the same width, but of different depths or thicknesses, are used, their strength is increased in proportion to the squares of their vertical thickness: when the joists are but 6 inches deep, they are in strength to those of 8 inches in depth, as 36 to 64—the square of 6 being 36, and that of 8, 64. The quantity of timber in the one case to that of the other is as 4 to 3—so that one-third more timber gives a strength double that of the other.

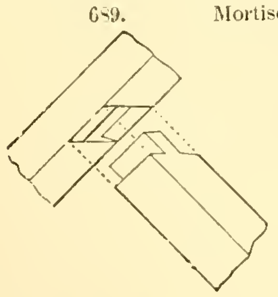
Where square oak joists are used, and the bearing 12 feet, their scantlings should be 6 inches, and laid at a similar distance apart. Such a floor contains the same quantity of timber as if entirely formed of 3-inch plank: the strength of timber being as the square of its vertical thickness, it results that the strength in these two instances is as 2 to 1: the floor composed of 3-inch plank is only half the strength of the other; but had the whole been formed 6 inches thick, instead of with joists 6 inches apart, it would have been 4 times as strong—the square of 3 being 9, and the square of 6, 36.

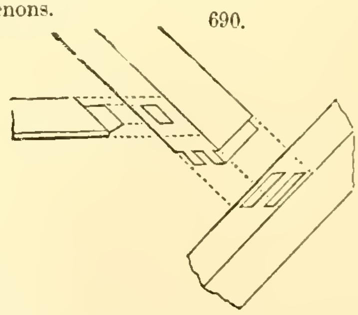
*Naked floors* are divided into *single-joisted, double,* and *framed floors:* and it must be remarked that unsawn timbers are considerably stronger than planks or scantlings cut out of a round tree. When a tree is cut longitudinally, and formed into two pieces, these will support less than they would do when united in the original tree, arising from the circular concentric rings which compose the tree being cut through, which renders the timber more compressible on one side than on the other; and as the texture is less close where it has been sawn, it is also more susceptible of change from humidity on alternation of temperature.

Joists whose width is less than half their vertical thickness, are subject to twist and bend if not strutted; and for this reason squared timber was usually employed by the builders in the middle ages; and we have numerous examples four or five hundred years old, where the timber selected has the pith in the centre, and the concentric rings nearly entire, being in a sound and perfect condition. Experience also teaches us that timber, whether sawn or unsawn, used for a floor of 16 feet bearing, composed of 12 joists, 8 inches square, placed at a distance of a foot apart, is much stronger than another of 24 joists, 8 by 4, placed edgeways, at a distance of 6 inches apart, although there is the same quantity of timber in both cases.

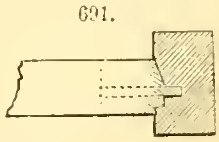
*Single-joisted floors* consist of one series of joists, which ought to be let down or halved on to wall-plates of a sufficient strength and scantling to form a tie, as well as a support to the floors. Each joist should be spiked or pinned to the timbers on which it lies. Wherever fireplaces occur, and the joists cannot get a bearing on the wall, they are let into a trimmer or piece of timber framed into the two nearest joists that have a bearing: into this the other joists are mortised. As the trimming joists support a greater weight, they must be made stronger than the others, and should have an eighth of an inch additional thickness given to them for every joist they carry. When the bearing exceeds 8 or 9 feet the joists should be strutted, or they will have an inclination to turn sideways: the joists in use, being generally thin and deep, require strutting on all occasions, and a rod of iron is often passed through them, which, being screwed up after the strutting-pieces are placed, gives the entire floor great solidity and firmness. The weight of a square of single-joisted floor varies from 10 cwt. to 1 ton, and the joists should never extend to a greater bearing than 20 feet in ordinary cases.

689. Mortises and Tenons. 690.





691.



*To find the depth of a joist,* when the length of bearing and breadth in inches is given: divide the square of the length in feet between the supports by the breadth of the joist in inches, and the cube root of the quotient, multiplied by 2·2 for fir and 2·3 for oak, gives the depth in inches. A single-joisted floor which has the same quantity of timber as a double floor, is considerably stronger, particularly if properly strutted, than the latter. The plates, bedded on the walls, upon which the joists are to be tailed down, should have their depth equal to half that of the joists, and their width half as much more. In many instances the plates are not bedded entirely in the wall, but have one-half resting beyond the face on corbels let into the wall, at a distance of 6 feet apart. To form the entaille or dovetail, great care should be used, to prevent the joist from drawing out of its place when once pinned down.

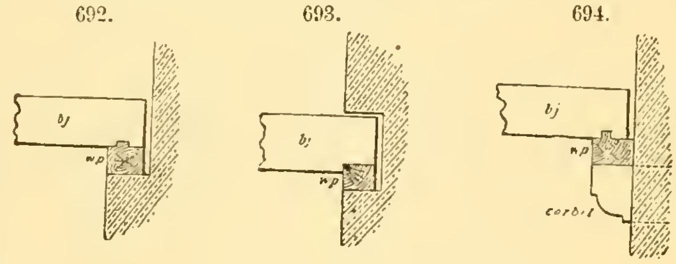
*Double floors* are formed of *joists*, *binders*, and *ceiling-joists*. The binders rest upon the plates bedded on the walls, and serve the purpose of supports to the joists which are bridged on them, as well as to the ceiling-joists, which are pulleys mortised into their sides. When the depth of a binding-joist is required, the length and breadth being given, divide the square of the length in feet by the breadth in inches, and the cube root of the quotient, multiplied by 3.42 for pine and 3.53 for oak, will give the depth in inches. When the length and depth are given, and the breadth is required, divide the square of the length in feet by the cube of the depth in inches, and multiply the quotient by 40 for pine and 44 for oak, which will give the breadth. The above rules suppose the binders to be placed at a distance of 6 feet from each other.

Binding-joists (Fig. 691) must be framed into the girders, and care must be taken that the bearing parts fit the mortise made for them very accurately: the tenon should be one-sixth of the depth, and placed at one-third of the depth, measured from the lower side. When binding-joists only are employed to carry the ceiling, their scantlings may be found in the same manner as those of ceiling-joists, which are small timbers, and only of a sufficient thickness to nail the laths to. When their length and bearing are given, their depth may be found by dividing the length in feet by the cube root of the breadth in inches, and multiplying the quotient by 0.64 for pine or 0.67 for oak, which will give their depth in inches. Ceiling-joists are usually notched to the under sides of the binding-joists, and nailed to them: this is better than mortising, which weakens the binder, and gives more labor.

Timber-Girders.*—*General Remarks*, applying only to plain beams. Girders should always be placed so as to have good supports for their extremities. Those intended to support floors should rest, therefore, on solid walls or piers, not over the windows or other openings. To insure this, it is sometimes necessary to lay them obliquely across the room, but an inclined position should be avoided if possible. It is better to provide very strong templates over the openings to carry the girder and throw the weight well upon the piers. The ends of all timber-girders should rest upon stone templates, and be perfectly clear of the masonry. Girders should be weakened as little as possible by mortises or joints of any kind which cut into them, especially at or near the centre of their length, where the greatest strain comes upon them.

Wall-Plates are pieces of timber built into or upon a wall, to support the ends of joists or other bearers. They distribute the weight thrown upon them by the joists, and give the latter a hold upon the side-walls, so that these are tied together. On the ground-floor the wall-plates generally rest upon an offset in the wall, as in Fig. 692. Above, also, they may rest on an offset, if there is a change in the thickness of the wall; or they may be built into the wall, as shown in Fig. 693, great care being taken that there is a free circulation of air round the ends of the joists; or they may rest on *corbels* provided for the purpose, as in Fig. 694, thus preventing all danger of decay by contact with the masonry and want of air.

692. 693. 694.




The joists are either simply nailed on to the wall-plates, or "notched" (Fig. 693) or "cogged" (Fig. 694) upon them. If the joists are of unequal depths, the notches are varied in depth also, so as to keep the upper surfaces of the joists in the same plane. Cogging gives the joists a good hold upon the wall-plates, so as to tie the walls in, but it is seldom done. Wall-plates are sometimes dovetailed into each other where they meet at the angles of a building; but there are great objections to dovetails, and it is better that they should be halved and bolted. Wall-plates should be in as long pieces as possible; and, when two or more pieces are required to extend along the length of the wall, they should be carefully scarfed together.

*Tredgold's Rule* for size of wall-plates:

| | | | | | |
|---|---|---|---|---|---|
| For a | 20-feet bearing, | $4\frac{1}{2}$ | inches by | 3 | inches. |
| " | 30 " | 6 | " | 4 | " |
| " | 40 " | $7\frac{1}{2}$ | " | 5 | " |

Bridging-Joists or "Common Joists."—These are generally laid about 12 inches apart from centre to centre, or sufficiently near to prevent the deflection of the floor-boards.

Joists should not be less than 2 inches wide, or they will be split by the nails holding the boarding, especially at the heading-joints where four nails come together. They should never be more than 3 inches wide if they are themselves to carry a ceiling (without the intervention of ceiling-joists), as the lower surface of the joists causes a blank space behind the ends of the laths, which interrupts the key for the plastering.

Strutting.—Joists more than 10 feet long should be *strutted* at intervals of about 7 feet, to make them stiff, and to prevent them from turning over sideways. The struts also add greatly to the strength of the floor by causing the pressure on the joists to be transmitted from one to the other.

*Herring-bone strutting* consists of small pieces, from 2 inches to 3 inches wide and 1 inch thick, inserted diagonally and crossing one another between the joists.

Pugging is plaster (coarse stuff) or other mixtures laid upon boards fitted in between the joists of a floor, to prevent the passage of sound or smell from the room below.

* The remainder of this article is mainly condensed from "Notes on Building Construction, adapted to the Requirements of the Syllabus of the Science and Art Department of the Committee of Council on Education, South Kensington." Rivingtons, London, 1876.

Slips of cork or list, along the upper edges of the joists upon which the boards are nailed, are recommended by Tredgold as a means for reducing the passage of sound. Felt or felt-paper over the boards and under the carpet have been used for the same purpose.

Trimming.—It often happens that, on account of flues, fireplaces, or from other causes, it is inadvisable to let the ends of the joists rest on particular parts of the walls, and it is necessary that they should be trimmed. When the joists are at right angles to the wall in which the flue or fireplace occurs, they are stopped short of the portion of wall to be avoided, and tusk-tenoned into a cross-beam called a "trimmer." This trimmer is tusk-tenoned at the ends, and framed in between the two nearest bridging-joists bearing on the wall, on each side of the portion to be avoided. The joists carrying the trimmer are called "trimming-joists." As they have to carry more weight than the other bridging-joists, they are made wider.

*Tredgold's Rule.*—To the width of the common joists add one-eighth of an inch for every joist carried by the trimmer, and that will give the width of the trimming-joists. When the trimming-joists are deeper than the others, they need not be so wide in proportion.

Floor-Boards are laid in several different ways.

*Plain-jointed.*—The boards are simply laid side by side, as close as possible (see Fig. 695), a nail

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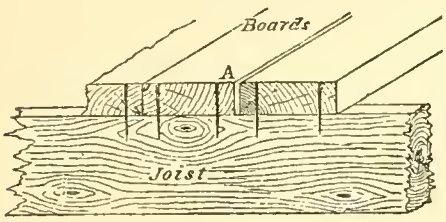


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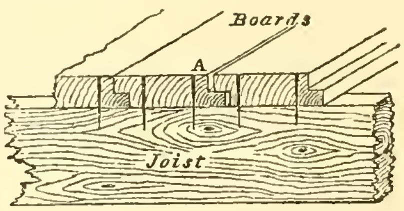


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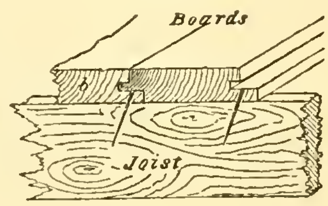


or generally two being driven through the boards into each joist. The inevitable shrinkage of the boards, as at *A*, will cause openings through this description of floor.

*Rebated*, of which the section, Fig. 696, explains itself. Here a considerable shrinkage may take place, as at *A*, without causing an opening between the boards throughout their depth.

"*Fillistered*" is another name for the joint shown in Fig. 696.

*Rebated, grooved, and tongued.*—One board can first be nailed, as shown at *b*, Fig. 697, and then the other board, upon being slipped into it, will be kept down by the form of joint. Thus the nails are prevented from appearing on the surface of the floor, which is sometimes desirable.

*Rebated and filleted.*—A rectangular rebate is cut out along the lower edges of the boards, as in Fig. 698, and the space filled in with a slip or "fillet," occasionally of oak or some hard wood. It will be seen that any opening caused by shrinkage is covered by the fillet, and the floor must be worn down nearly through its whole thickness before the fillet is exposed.

*Ploughed and tongued.*—A narrow groove is cut in the side of each board, and an iron or wooden

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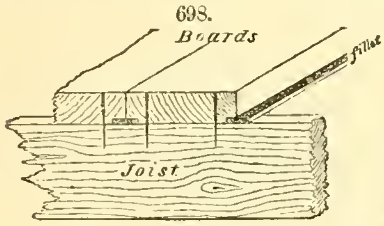


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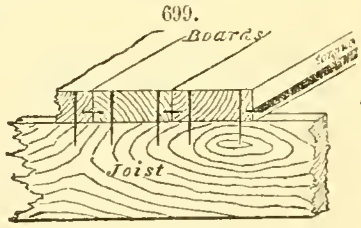


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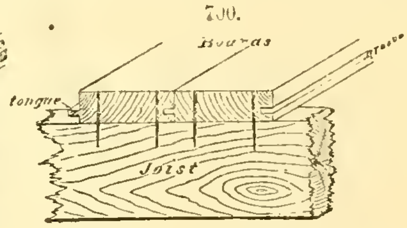
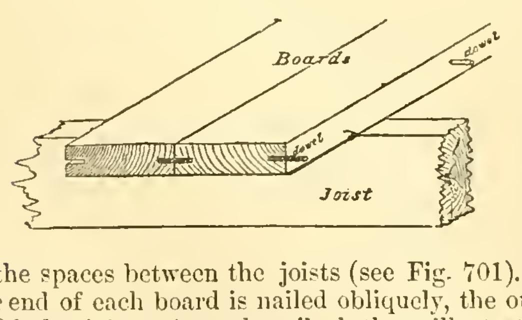



tongue inserted (Fig. 699). It will be noticed that this shares some of the advantages of the filleted joint, but the tongue is sooner laid bare when the floor is much worn. The tongue should be kept lower than the centre of the thickness of the boards, so that as much wear as possible may be got out of them before it is exposed.

*Grooved and tongued.*—In this joint, Fig. 700, the tongue is worked upon one board to fit the groove cut in the other. This is not an improvement on the joint last described; the tongue is necessarily thicker, and thus causes a thinner piece of wood to be left above the groove. This rots and flakes away if the floor is often washed.

*Doweled.*—Small oak dowels are fixed along the edge of one board to fit into holes in the other,

701.

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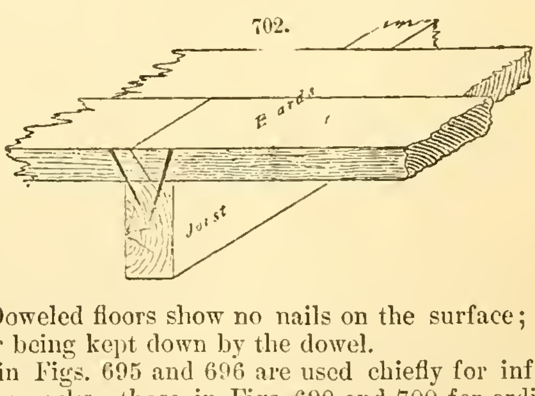



in the spaces between the joists (see Fig. 701). Doweled floors show no nails on the surface; only one end of each board is nailed obliquely, the other being kept down by the dowel.

Of the joints above described, those illustrated in Figs. 695 and 696 are used chiefly for inferior floors; that shown in Fig. 698 for warehouses or barracks; those in Figs. 699 and 700 for ordinary

floors of a high class; and that in Fig. 701 for very superior floors. The joints in Figs. 696, 697, and 700 necessitate the use of a larger quantity of boarding to cover a given surface than when the other joints are adopted.

Headings.—The boards in floors are seldom long enough to go right across the room. In such a case the joint between the end of one board and the next is called the "heading joint." Headings should always fall upon joists, and break joint with one another in plan.

*Square heading.*—In this, the ends of the boards simply butt against one another, similarly to the side-joints in Fig. 695.

*Splayed or beveled heading.*—The ends of the boards are splayed to fit one another, as shown in Fig. 702.

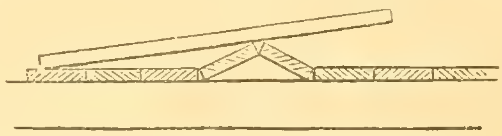
*Tongued heading.*—The ends of the boards are cross-grooved, and laid with a cross-grain wood, or a metal tongue, similar to that shown for the side-joints in Fig. 699.

*Rebated and tongued heading* is formed in the same way exactly as the joint shown in Fig. 697.

*Forked headings.*—In these the ends of the boards are cut into a number of sharp salient and reëntering notches, whose ridges are parallel to the surface of the floor. These notches fit one another, and form a tight joint. Such joints are sometimes used in oak floors, but they are extremely troublesome and expensive to make.

The best floors are those laid with narrow boards (from batten widths down to strips of 3 inches or 4 inches wide), as the shrinkage in each is less, and the joints can be kept tighter. Floor-boards are generally jammed tightly together as they are laid, by means of flooring-cramps; but in common floors they are sometimes laid folding, thus: Two boards are laid and nailed at a distance apart a little less than the width of three or four boards. These are then put into the space, and forced home by laying a plank upon them, and jumping upon it (see Fig. 703). The boards thus laid together are often of the same length, so that their heading-joints fall into one line, and are not properly broken.

703.



General Remarks on Floors.—The timbers that carry the weight should, as a rule, be laid the narrowest way of the room. The bearing timbers may be so arranged as to tie in the principal walls, or, if the building forms a corner, having two or more external walls, they may be laid in opposite directions in the alternate stories. All parts of timber built into walls should have clear spaces round them for circulation of air. Timbers passing over several points of support, such as joists over binders, joists or binders over party-walls, and similar cases, should be in as long lengths as possible, by which their strength is greatly increased as compared to what it would be if they were cut into short lengths, just sufficient to span the intervals between each pair of supports. Fixing uniformly-loaded timbers rigidly at the ends increases their strength by one-half, but this can seldom be done in practice. If the ends are built into the wall, they have a tendency to strain and destroy the masonry. The want of a free circulation of air causes the timber to decay, and in any case it soon shrinks and becomes loose. Tredgold recommends that floors should be laid with a slight rise in the centre (about three-fourths of an inch in 20 feet), to compensate for the settlement that will take place in the beams. All floors near the ground should be ventilated, to secure a perfect circulation of air round all their parts. This is easily done by inserting air-bricks in the walls. For the same purpose openings should be left in the sleeper walls carrying the intermediate wall-plates of ground-floors. The ground below the floor should be thoroughly drained, and covered with ashes and quicklime. It is sometimes asphalted all over to prevent damp from rising.

Ceiling-Joists are light beams to carry the laths for the plastering of the ceiling. They are fixed to the under side of the bearers of the floor, running at right angles to them—that is, in a single floor to the bridging-joists, in a double or framed floor to the binding-joists. They should be 12 inches from centre to centre; if more widely placed than this, the laths are likely to give with the weight of the plaster. Two inches is the best width for ceiling-joists; this is sufficient to nail the laths to. If wider, the under surface of the joist interrupts the key for the plaster. The mode of fixing ceiling-joists is generally to notch them and nail them.

Partitions are used to divide rooms from one another, instead of walls, to save space and expense.

*Quartered partitions* consist of framings filled in with light scantlings or "*quarterings*," upon the sides of which laths are nailed and plastered. These may be "framed" or "common."

*Bricknogged partitions* have the intervals between the quartering filled in with brickwork, upon which the plastering is laid.

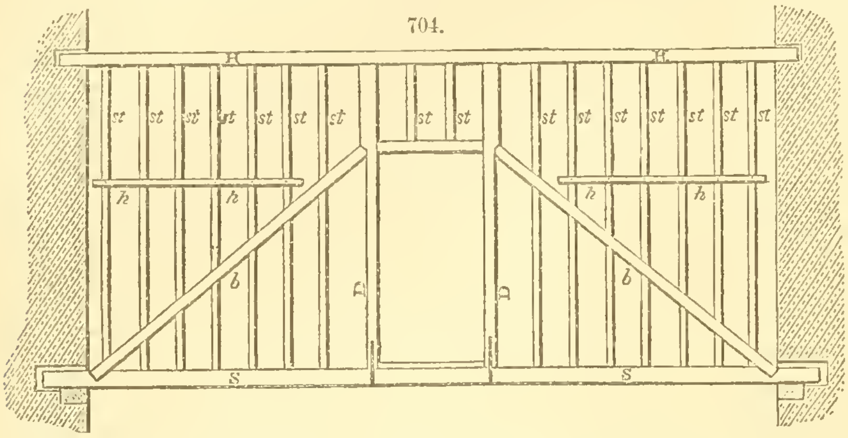
*General Remarks* (chiefly from Tredgold's "Carpentry").—Partitions containing timber should not be used on the floor next to the ground, as the wood is affected by the damp, and decays. Stone or brick walls are, therefore, preferable in such positions. A quartered partition sometimes rests on the party-wall of the ground-floor. This is not a good arrangement, as the partition becomes cracked in consequence of its being unable to settle together with the main walls to which it is fixed. Nor should the weight of the partition be allowed to rest on the floor below it, as it bears heavily upon the joists, cracks the ceilings below, and also settles and tears away from the ceiling above it. A better arrangement is to suspend the partition from the floor or roof above; this prevents the cracking of the cornice above the partition. Of course, if the weight of the partition be thrown upon either of the floors or the roof, these latter must be strengthened accordingly. By far the best plan, however, is to make the partition self-supporting, depending only on the main walls carrying its ends, and forming, in fact, a very deep truss. If the trussed partition be supported by two walls of very unequal height, they may settle unequally, and, if so, will cause it to crack. If the walls are of equal height and well founded, they will settle equally, and the partition moving with

them will sustain no injury. The framing of the truss should be so arranged as to throw the weight upon the points of support in the walls at the end of the truss.

*Framed partition with ordinary doorway in the centre.*—A truss of queen-post form may be used, as in Fig. 704, which is taken from Tredgold's "Carpentry."

The braces $b$ $b$ correspond to the principal rafters, and Tredgold recommends that they should be inclined at an angle of about 40° with the sill $S$ $S$. The door-head fulfills the part of the straining-beam, while the bottom plate or sill $S$ $S$ corresponds to the tie-beam, and may pass between the joists under the floor-boards. The ends of the top plate or "head" $H$ of the truss are received by the walls which support the partition, but they should not rest upon the walls unless the studs are secured by straps to the head. The filling-in pieces, "studs," "quarterings" or "quarters," *st*, should be of light scantling, just so thick—about 2 inches—that the laths can be nailed to them. They are tenoned to the top and bottom plates, butted and nailed on to the braces. They should be stiffened at vertical intervals of 3 or 4 feet by short struts called "nogging-pieces," or by continuous rails, $h$ $h$, notched on to the uprights and nailed to them.

704.




The studs $D$ on each side of the doors are called the "door-studs," "principal posts," "uprights," or "double quarterings." To avoid the waste of material caused by checking these out to form shoulders, as shown in Fig. 704, the heads of the braces may be housed and tenoned into them.

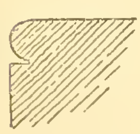
The studs should be placed at such a distance apart as will suit the length of the laths. These are usually 3 or 4 feet long, and the studs may be at 12 inches central intervals, so that the ends of the laths may fall upon every third or fourth stud.

Tredgold states that when a partition rests on a floor, or is otherwise supported throughout its length, it is better without struts or braces, the quartering being simply steadied by horizontal pieces between them. He also recommends that when extra strong and sound-proof partitions are required, the studs should not be filled in between the framing, but nailed on the outside as battens, and then plastered. Partitions should be made of very well-seasoned timber, and the joints carefully fitted. The whole should be allowed to stand for some time before being lathed, so that the timber may take its bearings, and twisted timbers may be put right before plastering. Wrought-iron tie-rods, also cast-iron sockets and shoes, are often used (for the same purposes as in roofs) in partitions of large size, or those which have to bear a great weight.

The weight of a square of partitioning may be taken at from 1,480 to 2,000 lbs. per square; the weight of a square of single-joisted flooring, without counter-flooring, 1,260 to 2,000 lbs.; the weight of a square of framed flooring, with counter-flooring, 2,500 to 4,000 lbs. Scantlings for the principal timbers of a partition bearing its own weight *only*: 4 × 3 inches for bearing not exceeding 26 feet; 4 × 3½ inches for bearing not exceeding 30 feet; 6 × 4 inches for bearing not exceeding 40 feet. If the partition has to sustain the weight of a floor or roof, the sizes of the timbers must be increased to meet the additional strain that will come upon them. The filling-in pieces should be just thick enough to nail laths to, about 2 inches. Any timbers more than 3 inches wide on the face, to which the laths are nailed, should have the corners taken off so as not to interrupt the key for the plaster.

Joinery Beads are narrow, convex, plain mouldings, in section generally parts of a circle. When the bead is formed upon a board, in the substance of the wood itself, its upper surface being flush, or nearly so, with that of the board, it is said to be "stuck" (see Figs. 705, 706, 707). If the bead is formed in a separate strip, and nailed or bradded to the board, it is described as "laid in" or "planted" (see Fig. 708).

705.



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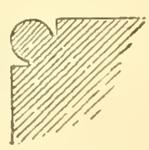

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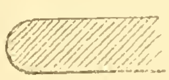


A *nosing or rounded edge* is formed by rounding the edge of a piece of stuff, as shown in Fig. 709. It is frequently used for finishing off the edge of a projecting board, such as the tread of a step, a window-board, etc.

*Quirked bead.*—In Fig. 706 the circular portion is the section of the bead, and the indentation at the side is called a "quirk."

A *double-quirked bead* is one with a quirk on each side, as in Fig. 707. It is also known as a "flush bead," because it is flush with the surface of the wood.

A *staff or angle bead* is a double-quirked bead formed upon an angle, as shown in Fig. 708. It is sometimes called a "return bead."

A *cocked bead* is one which projects above the surface of the board. In order to avoid reducing the whole surface of the board, the bead may be made in a separate strip, and planted upon it, or laid in a shallow groove, as in Fig. 708.

A *cocked bead and fillet* is one resting upon a flat strip or fillet slightly wider than itself, and planted on to the surface of the board.

*Reeding* consists of parallel beads placed close together.

The *torus* is a very large bead, surmounted by a flat strip or fillet. The distinction between a torus and a bead is, that the former is always surmounted by a fillet.

*Shooting* is simply making the edge of a board straight and smooth by planing off a shaving. A board is said to have its "edges shot" when both edges have been made smooth and true with a plane.

*Scribing* is cutting the edge of a board to fit an irregular surface.

*Chamfering* is taking off the "arris" or sharp edge, so as to form a flat, narrow surface down an angle. This is frequently done for ornament, and also to render the angle less liable to injury. Chamfers are also often used for the same purpose as beads, especially on the edges of boards forming a close joint, so as not only to form an ornament, but also to hide the opening caused by shrinkage

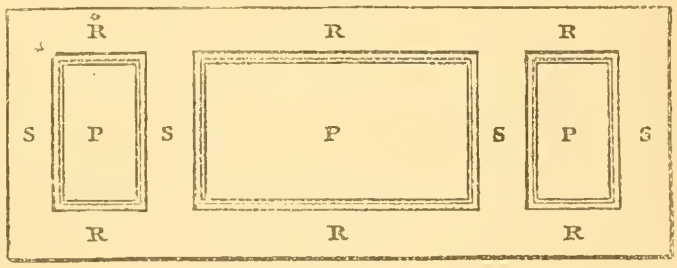
*V-joint* is the angle formed by the meeting of chamfers on two adjacent edges.

*Stop-chamfer* is one in which the chamfer is not carried to the extremity of the arris, but stopped and sloped, or curved up at the end till it dies away again into the square angle.

*Housing* consists in letting the whole end of one piece of timber for a short distance into another.

FRAMING.—Frames in joinery consist of narrow pieces of wood connected by mortise and tenon joints, and grooved on the inside to receive boards, which fill up the openings in the framing. In every frame the vertical pieces are called "stiles," *S S* (Fig. 710), the horizontal pieces "rails," *R R*. These constitute the framing itself, and in the example shown are filled in with panels, *P P*.

710.




The pieces of wood forming a frame should be narrow, so as to be affected as little as possible by shrinking under atmospheric influence. The inner edges of the stiles and rails are grooved to the depth of about half an inch to receive the panels, which should fit so tightly as not to rattle, and yet should be free to contract.

PANELING.—The boarding which fills in each opening of any piece of framing is called a "panel." There are several forms of panels, known by technical names, depending upon the manner in which they are respectively constructed and ornamented.

*Square and flat panels* are those in which the boards are of the same thickness throughout, thinner than the frame, sunk below its surface, and not ornamented by beads or mouldings. When the edge of the panel, close to the framing, is ornamented by a moulding, either "planted" or "stuck" on to the inner edge of the frame, it is designated as "moulded," or "moulded and flat."

*Flush panels* have their surface "flush," or in the same plane with the surface of the frame.

DOORS.—Internal doors should be at least 2 feet 9 inches wide and 6 feet 6 inches high. A usual opening is 3 feet, or 3 feet 6 inches. Very large rooms sometimes have doors 8 feet or more in width, and 8 feet to 10 feet high. Entrance-doors vary in width from 3 feet 6 inches to 5 feet. When a door is more than 3 feet 6 inches wide, it should be hung in two halves ("hung folding"), by which arrangement it requires less space into which to open, and the leaves are lighter. Doors should, as a rule, open inward, *from* a person entering the room. The hinges should generally be on his right, but this is sometimes altered by peculiarities of the position.

*Solid panels* are those in which the panel is in one piece, of the same thickness as the frame, and flush on both sides with its surface.

*Bead-flush panels* have a bead all round close to the inner edge of the framing.

A *ledged door* is the simplest kind of door made, and is used only for temporary or inferior buildings. The very commonest consist of vertical boards butted against one another, and connected by two or three horizontal pieces called "ledges" nailed across the back. In ledged doors of a better class, the boards are grooved or ploughed and tongued together, sometimes united by rebated joints, and nearly always beaded or chamfered.

A *ledged and braced door* has braces diagonally across the back in addition to the horizontal ledges, and generally housed into them.

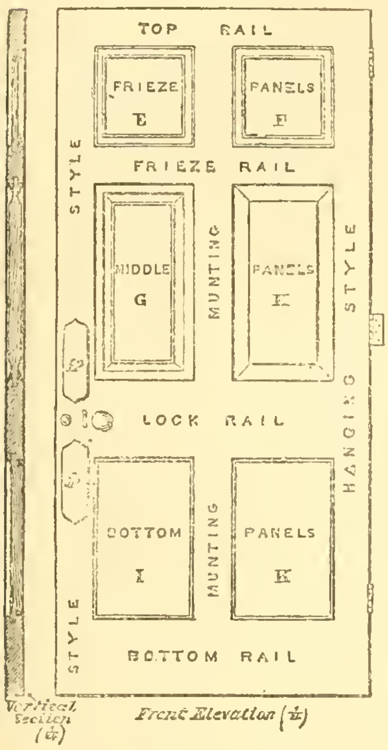
A *framed and braced door* consists of a frame strengthened by a middle or lock rail and diagonal braces, the edges of which are stop-chamfered, to give them a light appearance.

*Paneled doors* consist of a framework of narrow pieces of equal thickness put together with mortise and tenon joints, and grooved on the inside edges to receive the panels. Fig. 711 is a six-paneled door. The mode in which this is put together is shown in Fig. 712.

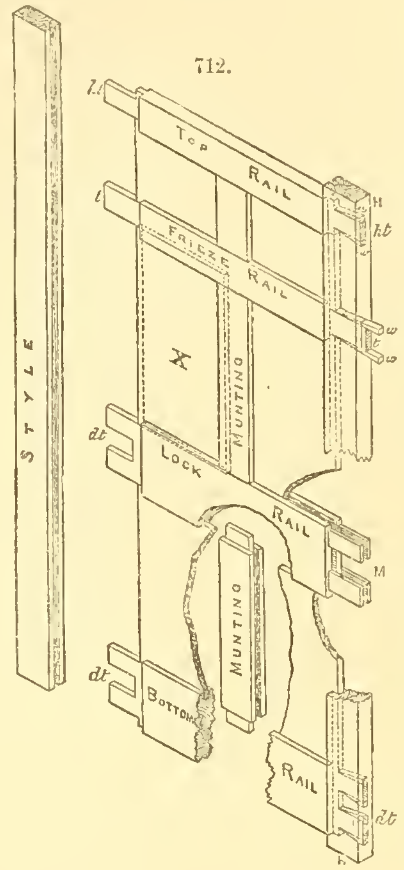
Fig. 712 shows one stile of the door detached; the other is in position, and supposed to be transparent, in order to show the construction of the tenons which fit into it. The rails and stiles are continuous throughout their length; but the munting is divided into three parts tenoned in between the rails. A portion of the door is broken away to show the construction of the munting between the bottom panels. It will be noticed that the stiles are longer than the height of the door, having projecting "horns" *H H*, which extend above and below the bottom rails. These horns are left until the door is wedged up, in order that there may be sufficient substance to resist the pressure of the wedges, which would otherwise, pressing in the direction of the grain, force out the wood beyond the mortise in the stile, and destroy the joint. These horns are, of course, removed when the door

is finished and cleaned off ready for fixing. The ends of the rails are formed with tenons of different kinds, as shown in Fig. 712. These fit into mortises in the stiles, and are then secured by wedges. The top rail has a single haunched tenon at each end, the frieze rail a common tenon at each end, and the bottom rail a double tenon at each end. The lock rail is provided at *dt* with a double tenon, strengthened by a haunch between them; thus the necessity of a very large mortise (which would cut the stile nearly in two) is avoided. When a mortise lock is used for a thick door, that end of the rail in which the lock is to be fixed should be provided with four tenons, as shown at *M*; between these there is room for the lock, which can be inserted without interfering with the tenons. The construction of this joint is shown in the figure, a portion of the stile having been broken away in order to show the tenons more distinctly. The common practice, however, is to make an ordinary double tenon in the centre of the framing (like that at *dt*), the result being that the formation of the mortise for the lock cuts away portions of the tenons, and weakens the joint.

711.




712.




The inside edges of the stiles, munting, and rails are grooved down the centre about half an inch deep and for one-third of their width, to receive the panels. The edge of the panel *X* is shown in dotted lines. The door, having been made, the tenons carefully fitted to the mortises, etc., is put together without any fastening, and left until immediately before it is required to be fixed, in order that it may have as long a time as possible to season. Before being fixed, the door is taken to pieces, the mortises cleared out, the tenons covered with glue, the stiles, munting, and rails tenoned into each other, and the panels inserted. The deal wedges *w w* are then dipped in glue and driven in as shown on each side of the tenons, the flat part of the wedge being next to the tenon. In the figure the wedges securing the frieze rail are shown as originally fixed. Those for the top and bottom rails have been cut off flush with the stile; this is shown so for the sake of illustration, but in practice it is not done until all the parts of the door are put together and "wedged up." The door should then be laid upon a flat firm surface till the glue is dry.

Windows.—Several rules are given by different writers for the sizes of windows as regards appearance. These need not be here entered upon. The undermentioned may be useful to regulate the size as regards internal arrangement.

The area of light should $= \sqrt{}$ cubic contents of room (Morris). The height generally from 2 to $2\frac{1}{2}$ times the breadth. There should be 1 foot superficial of window space to every 100 or 125 cubic feet of contents of the room in dwelling-houses, or 1 foot superficial to 50 or 55 cubic feet in hospitals (Galton). The window-sill should generally be about 2 feet 6 inches from the floor inside. Windows should, as nearly as the construction will admit, reach to the ceiling, for the sake of ventilation.

Windows consist of two parts: 1. The sash or sashes (including the bars) which hold the glass. 2. The frame carrying the sashes. The sashes may be fixed; hinged on the sides to open like a door, either in one flap or two; hinged at the top or bottom edge; suspended by lines over pulleys, with counterweights to slide up and down; arranged to slide laterally; or hung on pivots near their centres. The frames may be solid or hollow. The latter (which are called "boxed or cased frames") are required to receive the counter-weights when the sashes are hung over pulleys.

Stairs are arrangements of steps for conveniently ascending from one level to another.

*The staircase* is the chamber or space which contains the stairs. This may be a room of the exact size required, the walls of which closely surround and support the steps; or the stairs may be in a large apartment, such as a passage or hall, openings being left in the upper floors so as to allow headway for persons on the steps, and to furnish communication between the stairs and the different stories of the building.

Tread is the horizontal upper surface of the step upon which the foot is placed. Rise is the vertical height between two treads. Riser is the face or vertical portion of the step. Nosing is the outer edge of the tread. In most cases it projects beyond the face of the riser, and is rounded or orna-

mented by a moulding, being known, accordingly, as a "rounded" or "moulded" nosing. Fliers are the ordinary steps of rectangular shape in plan. Winders are the steps of triangular or taper form in plan, required in turning a corner or going round a curve. The small ends of winders are sometimes called the "quoins." A flight is a continued series of steps without a landing. A landing is the flat resting-place at the top of any flight. A half space is a landing extending right across the width of the stair. A quarter space is a landing extending half across the width of the staircase. The going of a stair is the distance from riser to riser. This term is, however, sometimes taken to mean the width of the stair, that is, the length of the steps. The going of a flight is the distance from the first to the last riser in the flight. The line of nosings is tangent to the nosings of the steps, and thus parallel to the inclination of the stair. Newels are posts or columns used in some kinds of stairs to receive the outer ends of steps. If the steps are pinned into the wall and there is no post, the staircase is said to have an "open newel." The handrail is a rounded rail, parallel nearly throughout its length to the general inclination of the stair, and at such a height from the steps as to be conveniently grasped by a person on the stairs. Balusters are slight posts or bars supporting the handrail.

*Dimensions of stairs.*—The dimensions of staircases and steps are regulated by the purposes for which they are intended.

*Length of steps.*—As a rule, steps should not be less than from 3 to 4 feet long, so as to allow two persons to pass, and in superior buildings they are very much longer.

*Tread and rise.*—The angle of ascent for a stair will depend upon the total height to be gained between the floors, and the space that can be afforded in plan. The wider the step the less the rise should be, as steps which are both wide and high require a great exertion to climb. Authorities differ slightly as to the proportion between the tread and riser.

The following rule is often adopted for steps of the dimensions ordinarily required in practice, i. e., those with treads from 9 inches to 14 inches wide: Width of tread × height of riser = 66 inches. Thus, with a tread of 12 inches, the riser would be $5\frac{1}{2}$ inches; with a riser of 6 inches, the tread would be 11 inches.

The tread of a step should, however, never be less than 9 inches in width, even for the commonest stair; while, for first-class houses and public buildings, the stairs may have treads from 12 to 14 inches wide. Flights should, when possible, consist of not more than 12 or 13 steps, after which there should be a landing, so that weak people may have a rest at short intervals. Two consecutive flights ought not to be in the same direction.

Different Forms of Stairs.—A *straight stair* is one in which all the steps are parallel to one another and rise in the same direction; thus a person ascending moves forward in a straight line.

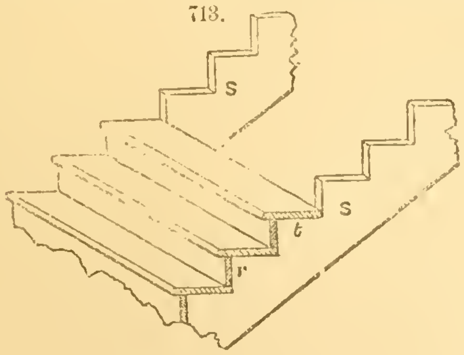
A *dog-legged stair* is so called from its being bent or crooked suddenly round in fancied resemblance to a dog's leg. In this form of stair the alternate flights rise in opposite directions. The ends of the steps composing each of these alternate flights are in the same plane with those of the other flight, so that there is no opening or well-hole between them.

A *geometrical stair* is one in which there is an opening or well-hole between the backward and forward flights.

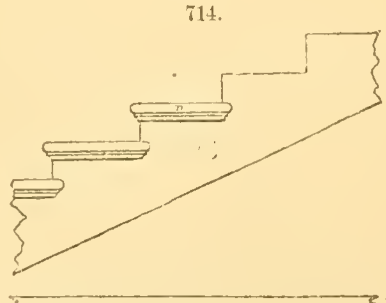
*Circular stairs* are composed of steps contained in a circular or polygonal staircase, toward the centre of which they all converge. All the steps are necessarily winders.

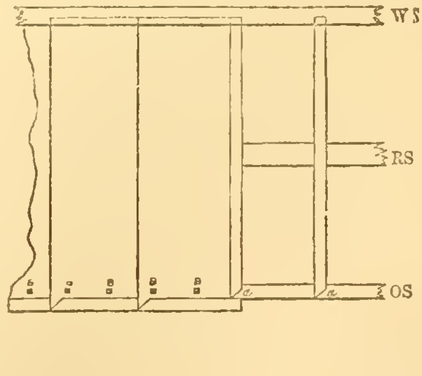
Parts of Wooden Stairs.—*Strings* are thick boards or pieces of timber placed at an inclination to support the steps of a wooden stair. Wooden stairs of the commonest description are thus constructed:

713.




714.



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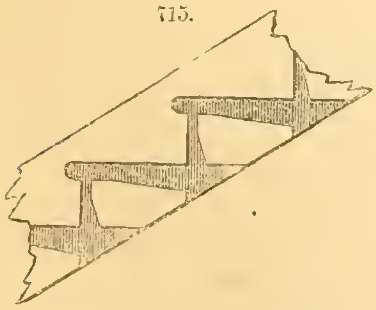


Two strings, *S S*, Fig. 713, are fixed at the slope determined upon for the stairs; in these, rectangular notches are cut, each equal in depth to the rise, and in width nearly equal to the tread of a step: upon these, boards are nailed, forming the treads *t* and risers *r*. In stairs of a better description

the outer strings are cut as above described; but the ends of the risers, instead of coming right through and showing on the outer surface of the string, are mitred against the vertical part of the notch in the string, as shown at *a a* in Fig. 714 (plan), the other end of the step being, as before, housed into a groove formed in the wall string. The outer extremity of the tread is also cut and mitred, as shown in Fig. 714, to receive a return moulding, forming the nosing of the end of the step. The mortises for the balusters are frequently dovetailed into the treads.

*Housed strings.*—In many common staircases the strings, instead of being notched out to receive the steps, are left with their upper surfaces parallel to the lower, and grooves are cut into their inner sides to receive the ends of the treads and risers; these grooves are called "housings," and the steps are said to be "housed" into the strings. Fig. 715 is an elevation of the inner side of a housed string, showing the sinkings or housings formed to receive the steps. Fig. 716 is a sectional elevation through the steps, showing the treads *t* and the risers *r* in position. These are secured by means of wedges *x y*, which should be well covered with glue before insertion. The treads are sometimes formed with two tenons at each end, which fit into mortises cut through the string.

*Open strings* are those, such as the cut strings, or cut and mitred strings, described above, which are cut so as to show the outline of the steps.

*Close strings* have their upper and lower surfaces parallel, the steps being housed into them as above described (see Fig. 716).

*Wreathed string* is one formed into a continuous sweep round the well-hole of a geometrical stair.

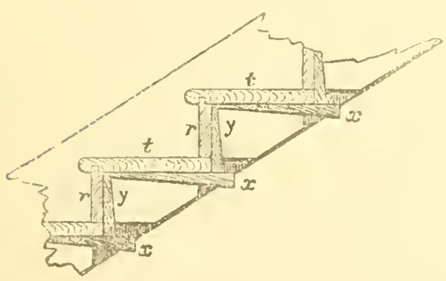
The *wall string* is the string up against the wall, and plugged to it (*W S*, Fig. 714).

The *outer string* is the string at the end of the steps farthest from the wall (*O S*).

A *rough string* is an additional support between the former two, in stairs of more than 3 or 4 feet in width (*R S*); called also a *carriage*. In very wide stairs two or more rough strings are used.

*Wooden steps* are formed of boards, as shown in Fig. 717. The risers are united to the treads by

716.

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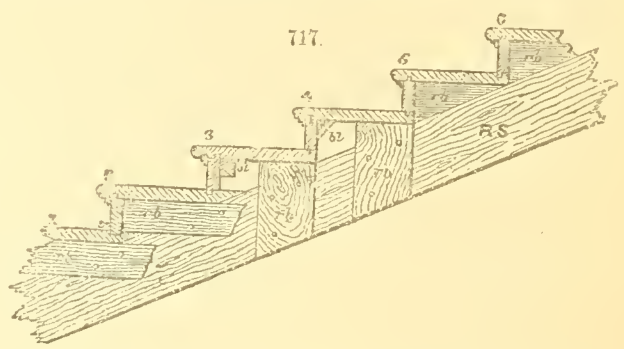


joints, which may be grooved and tongued, as in steps 5, 6—feathered, as in step 4—or rabbeted, as No. 3; in every case the joint is glued. The riser often has only its upper end tongued, the lower butting upon the tread below. This is not so good a construction as that shown at 3. A common practice is to house the lower edge of the riser into the tread below, as at *x*. The tread is sometimes tongued into the riser, but that is not a good construction.

The joint between the tread and riser is strengthened by small blocks glued into the inner angle, as shown in steps 3 and 4; these may be either rectangular or triangular in section. The inner ends of the treads rest upon rough strings *R S* (if any), and they are frequently further supported by rough brackets, *r b*, attached to the rough strings or carriages. These brackets may be pieces nailed alongside the string, as in steps 1, 2, 3, 4, or triangular pieces fixed to its upper surface, as in 5 and 6. The treads project over the risers, and are finished with a rounded or a moulded nosing, the projection of the nosing being generally equal to the thickness of the tread. When a moulded nosing is adopted with an open string, the moulding is returned at the end of the step, being mitred at the angle. The mouldings are generally planted on under the rounded nosing of the tread. The treads should be of oak or other hard wood, and may be $1\frac{1}{8}$ inch thick for steps 4 feet long—the thickness being increased by one-eighth of an inch for every 6 inches added to the length of the step.

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CAR, REFRIGERATOR. See Ice-making and Refrigerating Machinery.

CARS, RAILWAY. See Railway Cars.

CARTON PIERRE. Paper pulp mixed with whiting and glue. It is pressed into any desired shape, in sectional moulds of oiled plaster. It is largely employed for decorations in relief, to imitate sculpture in theatres, and also for the manufacture of fancy articles, picture-frames, etc.

CARTRIDGE-MAKING MACHINERY. The successful invention of the self-primed metallic-case cartridge has greatly simplified the construction of breech-loading small arms. Prior to its introduction and use, the prevention of the escape of flame through the joint of the breech was of difficult if not impossible accomplishment; and the complicated arrangements of the breech mechanism had to be resorted to, with at best unsatisfactory results. The metallic cartridge overcomes this difficulty, being itself a perfect gas-check, renewed at every round, preventing foulness and also wear of the mechanism. So important an element is it, that it may be said that, with a perfect cartridge, the most indifferent breech arrangement can be used with safety and efficiency. Among the benefits claimed for the metallic cartridge may be mentioned its completeness and simplicity, and the facts of its being self-primed and of sufficient strength to withstand the roughest usage; its accuracy, because of the coincidence of the axes of the bore and bullet; and added to these, the impossibility of firing but one cartridge at a time.

Cartridges are made of various sizes and with differing forms of projectile, as the short round, long conical, and taper conical swaged balls. The explosion of the cartridge is caused either by "centre" or "rim" fire, according as the percussion composition is concentrated at the centre or rim of the rear portion. The system adopted by the U. S. Ordnance Department and leading cartridge manufacturers is known as the centre-fire. By concentrating the percussion composition in the centre of the head, the quantity used is reduced to a minimum—to less than one-fourth of what is required to prime the entire circumference in the rim-fire; and this smaller quantity is so much better protected as not to be at all liable to accidental explosions. The central portion of the head has more elasticity than the rim, and is better adapted to resist the strain upon it from the sudden action of the fulminate, besides having the additional advantage of permitting the reënforcing of the rim, thus strengthening the weakest portion of the cartridge-case.

The regulation U. S. cartridge consists of the following parts: The *case*, the *cup-anvil*, half grain of percussion composition, 70 grains of musket powder, and a lubricated leaden bullet weighing 450 grains.

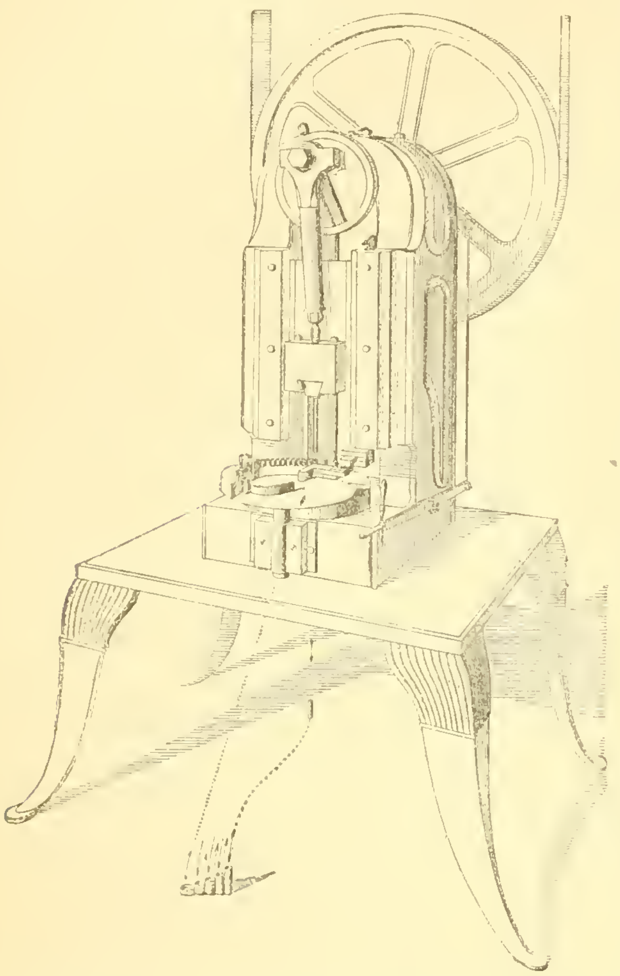
The *case* is the copper tube which forms the receptacle for the powder-charge, the percussion composition, and the bullet. Its exterior conformation is designed to facilitate its ready extraction from the gun. Besides the rim at the closed end, which is intended primarily to assist extraction, the case is tapered from the rear to a point where it seizes the bullet.

The *cup-anvil* is a small metallic cup of sufficient rigidity to resist the blow of the hammer, and of such form as to insure the passage of the flame to the powder-charge. It is provided with a circular recess or cavity, on which the percussion composition is deposited. Two little vents at the extremities of a diameter of this recess direct the flame to the charge. The cup when charged with the composition is placed within the copper case, pressed snugly against its closed end, and crimped firmly into position. Cups and shell are of copper. The bullet enters more than half its length into the case, in order that the lubricant in its grooves may be entirely covered and protected. To render the cartridge water-proof, the edge of the case is crimped hard against the bullet. In making the cases for the United States army, sheet copper of No. 2 wire gauge, obtained in strips 35 inches long, 3.3 inches wide, and from .025 to .027 inch thick, is employed, each strip giving material for 40 cases.

Cartridge Manufacture.—The first operation is performed by a double-acting press, to which the strips, after being straightened and oiled, are fed by hand, a small stop on the die-plate regulating the length of feed. The first shape given to the case is that of a flat circular disk 1.7 inch in diameter. The punch is essentially a punch within a punch, the exterior one cutting the disk clear from the strip, while the interior one descends and forces the blank through a tapered die, giving it a shallow cup-shape 1.06 inch in diameter and .55 inch deep. After passing through and beyond the tapered die, the cup expands slightly, and is stripped from the interior punch as the latter ascends. In order to draw the cups to the dimensions of the finished cases required, they are subjected to the action of four additional punches and dies of decreasing sizes, so as gradually to elongate them while reducing their diameters. These draws are made by the single-action presses, each having a single punch and die. Fig. 718 represents a single-acting punch. At the second drawing the tubes are annealed, to restore ductility. *The annealing* is done by placing the tubes in a perforated iron cylinder, heating them red-hot in a charcoal fire, revolving the cylinder to equalize the heat, then plunging them into a solution of 1 part of sulphuric acid and 15 parts of water. They are then thoroughly washed to remove all trace of acid. The pickle is used to remove any scale or oxide occasioned by the annealing. The fourth and finishing draw having left the tubes of unequal lengths and with ragged edges, it is necessary to have the tube trimmed, which is accomplished by the *trimming machine*. The tubes are placed in the trough of this machine, whence they are taken up by a revolving mandrel, against which, and just inside of a shoulder upon the same, the edge of a circular cutter is pressed. The tube, when brought into position by the mandrel, is cut clean and even by

the cutter, a stripper removing the tube and scrap after each operation. This machine trims at the rate of 80 a minute. In all the operations previous to and succeeding the annealing, lard oil of the best quality is the lubricant used. But as the smallest particle of oil will impair the efficiency of the fulminate, it is of importance that all vestiges of it be removed. To accomplish this, the tubes are placed in a potash solution.

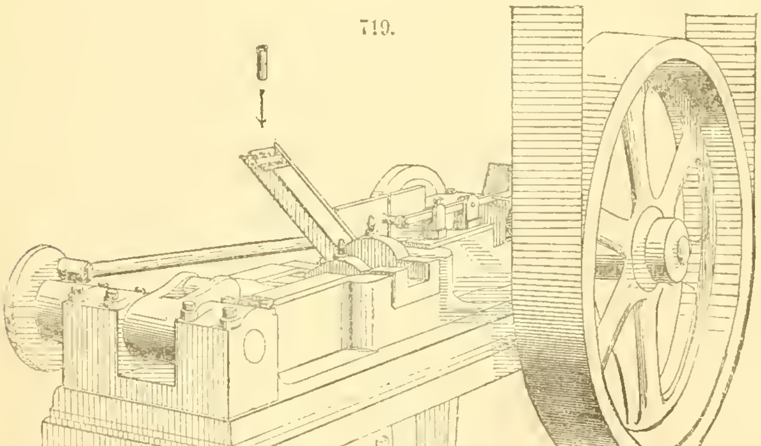
718.



The head or rim of the case is next formed by the *heading machine*, Fig. 719. This machine consists of a horizontal die, countersunk at one end for shaping the head, a feed-punch to insert the tubes into the die, and a heading-punch to flatten the closed end of the tubes into the countersink. The tubes, which are a little longer than the headed cases, are fed into the inclined trough of the heading machine, whence they are taken up on the feed-punch. A shoulder on this punch, at a distance from its extremity equal to the inner depth of the headed case, prevents it from extending to the full depth of the tube, and any surplus of metal is thereby left at the closed end of the tube for the formation of the head. The feed-punch inserts the tube into the die, and holds it there while the heading-punch moves forward by a powerful cam, and presses and folds the unsupported projecting portion of the tube into the countersink of the die, forming and accurately shaping the head or rim. The headed case, being left in the die as the feed-punch recedes, is pushed out by the succeeding tube and thrown by a flipper into the receptacle below. This machine is fed at the rate of 65 cases a minute. The tubes are now subjected to a temperature of 125° to remove all moisture.

This portion of the shell being ready, the "cup-anvil" is made. It is punched out by the double-action press, of unannealed copper in strips 20 inches long, 3.125 wide, and 0.48 thick. The cups are formed at the rate of 75 a minute. They now go to the *cup-cutting and trimming machine*, which consists of a revolving rose-cutter, made of a number of small cutters that can be changed and sharpened at pleasure. They afterward pass to the *cup-venting machine*, where the vents are punched in the trimmed cups by a two-pointed punch and corresponding dies. The cups are fed by a revolving plate at the rate of 70 per minute. The circular depression in the bottom of the cup which serves as a receptacle for the fulminate is formed by the *cup-impression machine*, to which the cups are fed through a vertical trough at the rate of 80 per minute. The trough has a flat pan at the top, into which the cups in quantities are emptied, and where they are arranged so as to present the proper end to the punch in passing through the machine. The cups are now washed.

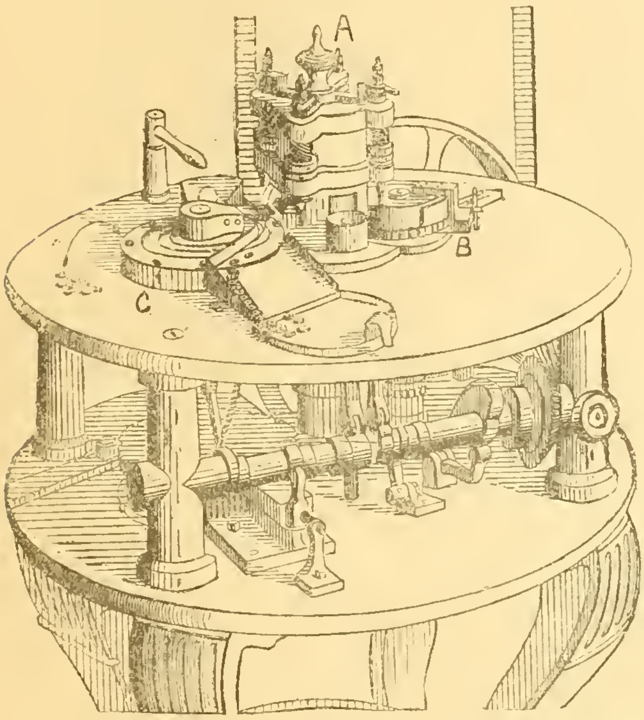
719.



The next operation is the priming of the cup, which is done by the *priming machine*. The percussion composition which is used consists of fulminate of mercury, by weight, 35 parts; chlorate of potash, 16; glass dust, 45; gum arabic, 2; and gum tragacanth, 2. This composition, which is of the consistence of a thick paste, is deposited in the recess of the cup by the *cup-priming machine*, Fig. 720, of which the principal parts are: 1, the central revolving spindle *A*, with four tubular feeders at its head, which deposits the percussion composition in the cups; 2, the magazine *B*, on the right; and 3, the circular plate *C*, on the left, on which the unprimed cups are fed to the machine. The four tubular composition-feeders at the head of the spindle consist each of a small depending stem, down which a closely-fitting tube is made to slide, the lower edge projecting a little below the end of the stem. By the revolving motion of the spindle these tubular feeders are brought successively over the magazine and over the cups to be primed. At the moment a feeder is presented over the magazine (which is a shallow dish

containing the composition), the latter rises until its bottom is in contact with the tube, a slight shaking motion of the magazine during its progress serving to deposit compactly into the open projecting end of the tube a sufficient quantity of composition for the priming of a cup. The magazine then recedes, while the revolving spindle carries the charged feeder to the circular plate *C* on the left, which presents the cup for priming. The motion of this plate is from left to right, while

720.

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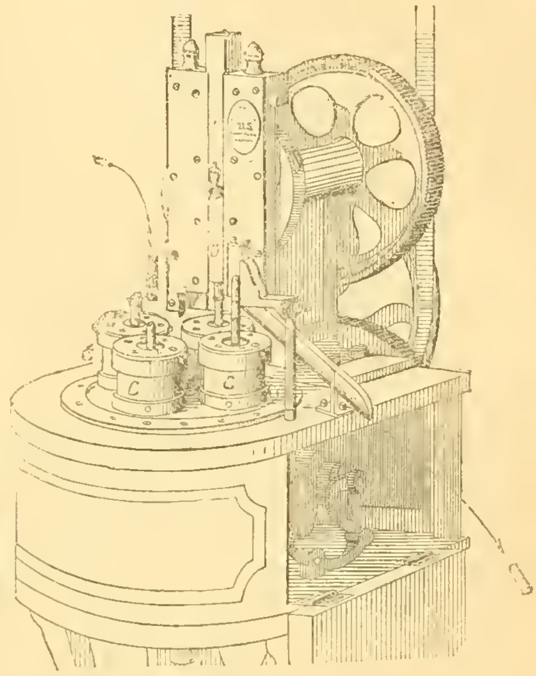
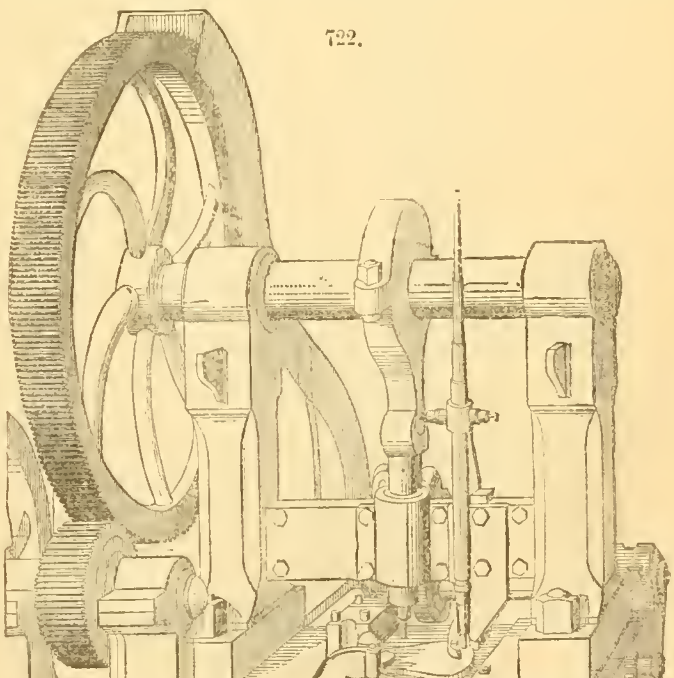



that of the spindle is from right to left, whereby the feeders and cups are made to meet and leave each other in opposite directions. The plate is provided with eight upright movable stems, on which the unprimed cups are fed. As the cups and feeders are brought by the revolutions of the plate and spindle in a vertical line with each other, the cups are raised by their stems so as to receive the composition exactly in their circular recesses from the tubes of the feeders. The tube at the moment of contact with the cup slides up its depending stem, and frees the composition from its end, which is pressed by the upward motion of the cup snugly into the circular recess. A specific quantity of composition is thus deposited at each operation. This machine primes at the rate of 35 cartridges a minute.

722.

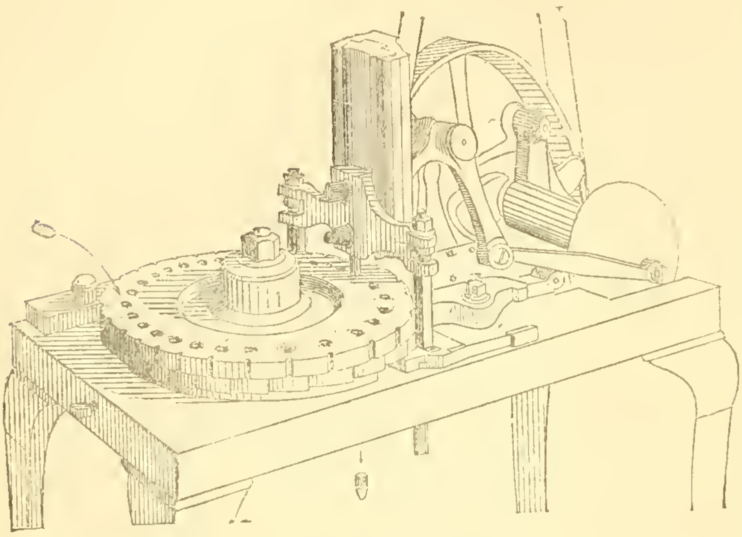


While the composition is still moist in the circular recesses of the cups, the latter are put into the headed cases and crimped into position, the cases being tapered at the same time. This operation is performed by the *tapering machine*, Fig. 721, which consists of four vertical tapered dies *C C*, with stems projecting from their centres, on which the cases and cups are fed; the crimpers, which work from the sides of the dies; and the descending punch *D*, which forces the cases into the dies. The primed cups are placed on the ends of the stems projecting from the dies, and the cases are placed over them. By the revolution of the horizontal plate on which the dies are placed, each die is in succession brought under the descending punch, which forces the cases into the dies and presses their heads hard against the primed cups, while the crimpers move forward from the side and bite the cups snugly and firmly into place. The central stem rises out of the die as the latter leaves the punch, and the case is removed by a spring.

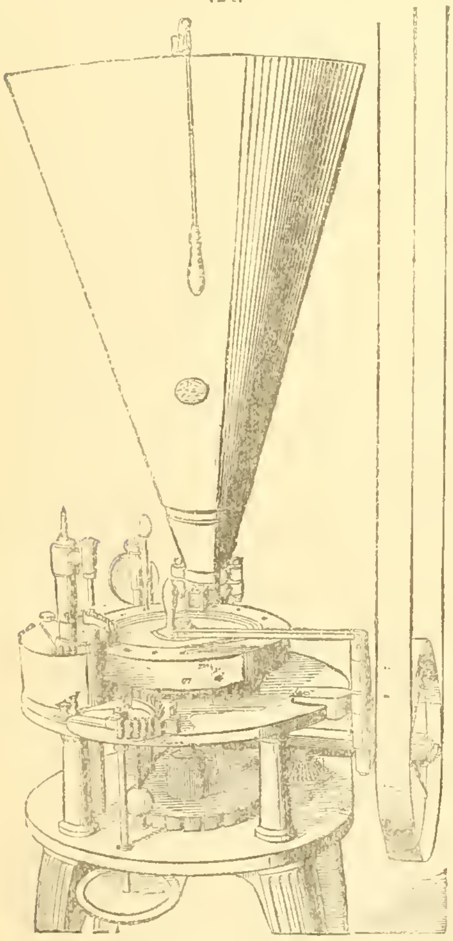
Bullet-making.—The bullets used are generally of the elongated variety, and are made either by compression, swaging, or casting. Compressed bullets are considered the best, as they are uniform in size and weight, more homogeneous and more accurate, and give better results, than the cast and swaged varieties. The lead used should be pure and soft, of a specific gravity 11.35, increased by

pressure to about 11.45, and which melts at 600° F. and volatilizes at red heat. The lead is first cast into cylindrical bars .59 of an inch in diameter and 20 inches long. They are then rolled, having a diameter of .42 of an inch and 36 inches long. These bars are fed to the *bullet-forming machine*, Fig. 722, through a vertical tube above a horizontal cutter, which cuts at each stroke sufficient metal to form a bullet, and transfers it to the die, in which by means of a vertical punch the bullet with its grooves is formed. The surplus lead is forced out at the junction of the dies, in the direction of the longer axis of the bullet, and at the junction of the punch and dies at its head. The dies and punches for this machine are made of the finest cast-steel. The dies are cut out to the form and dimensions of the bullet, and have as hard and smooth a surface as it is possible to give them. They are hardened in cold water, and the temper drawn to a light straw-color. They are made in such a manner that only small portions of their faces, just surrounding the base of the bullet, may be in contact while the bullet is being formed. A bullet machine makes 30,000 bullets in ten hours. The operation of trimming the bullets is performed by the *bullet-trimming machine*, Fig. 723. The bullets are fed by hand into a revolving perforated circular plate, whence they are forced by a punch through trimmers, which open from the point to the base of the bullet and conform to its shape, a cutter at the same time passing over the base. After this they are forced by the punch through a gauge under the trimmer. The bullet being finished, the next step is to lubricate it, for which purpose the following is considered the best lubricant: bayberry tallow, by weight, 8 parts; graphite, 1 part. The lubrication of the bullet is done by the *lubricating machine*. The lubricant is moulded into cylinders of about 10 inches in length. These cylinders are fed to the machine through a vertical tube, pressure being applied to keep the supply constant. The bullets are placed by hand in a perforated plate revolving vertically, and are forced by a punch through the sizing gauge fixed in the bottom of the tube, which is pierced with small holes. The lubricant is forced through the holes into the grooves of the bullet.

723.



724.



The cases are now loaded with powder by means of the *loading machine*, Fig. 724, which consists of a revolving circular plate with holes and a hopper and powder measure. The cases and bullets are fed upon revolving plates, 35 a minute. The former are lifted into the holes or receivers, passed under the hopper and measure for a charge of powder, and then under the bullet-feeder for a lubricated bullet. In order to insure a full charge of powder in each cartridge, the machine is provided with a bell, which gives notice to the operative of any failure in this particular. The edge of the case is then crimped on the bullet. The receivers are smaller at the top, where the bullet enters, than at the bottom, where the case is received, the diameter of the former being only equal to that of the interior of the open end of the latter. After the bullet has been pressed into the case the cartridge is lifted, so that the edge of the case is forced into the conical surface of the receiver, between its larger and smaller diameters. The powder is placed in a large pasteboard hopper about 2 feet above the machine, and is fed to the cases through a paper tube 1 inch in diameter. The hopper and tube stand inside of a large conical shield of boiler iron. After loading, the cartridges are wiped clean and packed in wooden boxes.

For much of the foregoing details we are indebted to the Winchester Repeating Arms Company of New Haven, Conn. See also reports of Chief of Ordnance U. S. A., since 1870. G. H. B.

CARVING TOOLS. In Figs. 725 to 739 are represented the various tools used in hand-carving in wood. The chisel, Fig. 725, is of various widths, from one-eighth of an inch to an inch, has a straight edge, and is used for plane surfaces which are square, removing superfluous wood and grounding. It is the most necessary tool of the set. The gouge, Fig. 726, has a curved edge of various sweeps, according to the depth to be cut. It ranges from almost flat to the exact half of a circle, about eight different sweeps. The skew-chisel, Fig. 727, is a variation of Fig. 725, the edge

being ground back from either corner, being right or left hand. It is useful for working out the inside corners of angles, where the edge of Fig. 725 would be too wide. The parting tool, Fig. 728, is a sort of gouge with an angular edge. Its cut is V-shaped, and it is quite essential for various purposes of cutting angular grooves.

725.—Carving Chisel.

726.—Carving Gouge.

727.—Skew Carving Chisel.

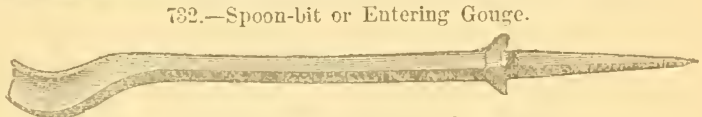
728.—Bent Parting Tool.

729.—Spoon-bit Parting Tool.

730.—Spoon-bit or Entering Chisel.

731.—Skew Spoon-bit Chisel.

732.—Spoon-bit or Entering Gouge.



733.—Back-bent Entering Gouge.

734.—Veining Tool.

735.—Fluting Gouge.

736.

737.—Double-bent Fluting Gouge.

738.—Scraper.

739.—Riffling Tool.

They are made either straight or bent. Fig. 734 is only a variation of the parting tool, quite narrow, and used to engrave the veins of leaves and similar work. The parting tool is often used for the same purpose. Figs. 730 to 737 are simple variations of the tools already mentioned. Their peculiar shape adapts them for use in confined spaces, where the shanks of the other tools could not be carried back far enough to make a clear cut, the relief of the carving being in the way. Fig. 738 is a scraper, and Fig. 739 a riffling tool for finishing.

For machine-carving, see MOULDING AND SHAPING MACHINES.

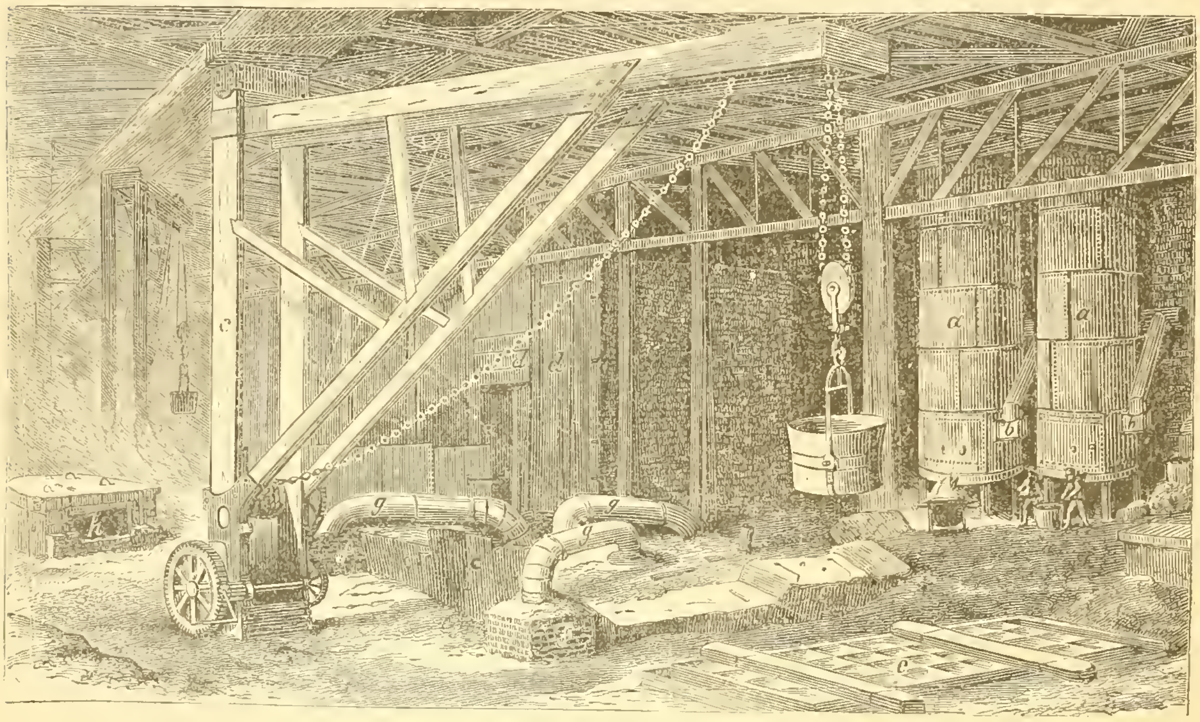
CASTING. The forming of metals and other substances by pouring them while in a liquid or melted state into moulds, and allowing them to solidify by setting or cooling. (See PATTERN-MAKING AND MOULDING, LADLE, FURNACES, BLAST, and IRON-MAKING MACHINERY.) The term, when applied to the casting of metals, is used synonymously with founding, and the place where the work is done is called a foundry.

For melting the metal to be cast, the cupola furnace is most commonly used. This will be found described under FURNACE, CUPOLA. The reverberatory furnace (see IRON-MAKING MACHINERY) is sometimes employed, and has the advantage of making strong, close, and safe castings. The circumstances under which this form of furnace may be used in preference to the cupola are as follows: when there are no means for obtaining sufficient blast for a cupola; when it is necessary to melt down such large masses of metal as cannot be managed in the cupola; when it is required to bring a given pig iron by deoxidation to its highest point of tensile resistance, as in gun-founding; or when it is necessary to erect a foundry under circumstances where a cupola with blast could not be built or worked. Under most other circumstances the cupola is to be preferred, as the reverberatory is neither economical in metal nor fuel, except where the operations are constantly going on from day to day on a very large scale, and where good bituminous coal is cheap.

*Arrangement of a Foundry.*—A well-appointed foundry, in addition to the room required for the actual work of moulding and casting, should have rooms for storing and preparing the materials of the moulds, such as grinding and sifting the sand, loam, coal, coke, plumbago, or charcoal. There should also be a workshop for making the patterns which are to be used in the formation of the moulds. The moulding-room embraces an area of greater or less extent, but even in moderate establishments it is necessarily of considerable size. Where heavy articles are founded there are huge cranes for lifting and moving moulds and castings from one place to another. The floors of

such foundries are also covered or rather filled with moulding-sand to a considerable depth, varying from 5 to 10 feet. Fig. 740 represents the interior of a foundry for heavy castings. The principal parts are as follows: *a a*, cupola furnaces; *b b*, tuyeres; *c*, crane; *d*, ovens for baking moulds; *e*, cope of a greensand mould, made in the floor-bed; *f f*, temporary furnaces for forcing heat through the pipes *g g* into a large mould; *h*, mould of a steam-cylinder, placed in a pit and in process of

740.



completion. In one part of the room, usually at one side, and sometimes adjoining another room for making light castings, stands the furnace for melting the metal.

*Consumption of Fuel.*—According to the experiments of Dulong, 1 lb. of carbon, combining with the necessary quantity of oxygen to form carbonic acid, develops 12,906 units of heat. The specific heat of cast-iron being about 13°, the melting-point 2190°, and coke containing 82 per cent. of carbon, then to heat a ton of cast-iron of a temperature of say 40° to a temperature of 2190° would require

$$2190 - 40 = \frac{\overset{\text{Heat.}}{2150} \times \overset{\text{Iron.}}{2240} \times \overset{\text{Sp. heat.}}{13}}{12906 \times .82.} = 59.1 \text{ lbs. coke.}$$

This is supposing that the whole of the carbon is converted into carbonic acid; but if by any means carbonic oxide is formed, a very different result is obtained, 1 lb. of carbon burning to carbonic oxide then evolving only 4,453 units of heat. If, however, by admitting air above the zone where the oxide is formed, we recover 4,478 units, this + 4,453 gives 8,931, which is a little over two-thirds of the available heat to be got out of 1 lb. of carbon, allowing 10 per cent. for moisture in the coke, 10 per cent. for radiation, and 20 per cent. for loss of heat passing off at the top of the cupola, or 40 per cent. in all. Mr. N. E. Spretson concludes that the amount of coke per ton of metal should not exceed 112 lbs., although the actual consumption is, as has been shown, usually much higher. Mr. Edward Kirk states that "the percentage of fuel actually required to melt a ton of iron will vary according to the quality of the fuel used, the construction of the cupola, the pressure of the blast, the way in which the iron is charged, the way in which the bed is burned, and the amount of iron melted. A larger percentage of fuel is required to run off a small heat than would be required for a large heat in the same cupola." The same authority gives as examples of the most economical melting in a cupola the following: "7 lbs. of iron to 1 lb. of coal; 8 lbs. of iron to 1 lb. of Connellsville coke; 4 lbs. of iron to 1 lb. of gas-house coke made from Pittsburg coal." Average melting in foundries he states to be "about 4 lbs. of iron to 1 of coal, 5 lbs. of iron to 1 of Connellsville coke, and 3 lbs. of iron to 1 of gas-house coke."

*Table showing Percentages of Fuel and Castings in seven large Stove Foundries in Albany and Troy, N. Y., for* 1876. (*Compiled from Kirk's "Founding of Metals."*)

| | 1 | | 2 | | 3 | | 4 | | 5 | | 6 | | 7 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Tons. | Lbs. | Tons. | Lbs. | Tons. | Lbs. | Tons. | Lbs. | Tons. | Lbs. | Tons. | Lbs. | Tons. | Lbs. |
| Gross amount of iron melted... | 2,059 | 1,087 | 2,817 | 1,420 | 1,818 | 930 | 1,009 | 415 | 3,328 | 84 | 6,695 | 1,197 | 2,009 | 987 |
| Amount of stock melted....... | 1,300 | 1,860 | 1,842 | 1,871 | 1,123 | 42 | 651 | 702 | 2,118 | 521 | 4,276 | 1,042 | 1,250 | 1,760 |
| Amount of cleaned castings, net | 1,344 | 919 | 1,960 | 889 | 1,128 | 1,407 | 664 | 707 | 2,216 | 987 | 4,433 | 975 | 1,294 | 819 |
| Percentage of cleaned castings produced to total iron melted. | 57.70 | | 62.12 | | 55.42 | | 58.62 | | 56.35 | | 58.41 | | 59.50 | |
| Percentage of coal used in melting.................... | 15.55 | | 14.51 | | 15.17 | | 17.22 | | 16.12 | | 15.08 | | 18.10 | |

*Loss of Iron in Melting.*—Mr. Kirk gives the average loss as follows: "In stove-plate foundries, from 2 to 8 per cent.; in machinery foundries, with the average iron, from 4 to 10 per cent.; on old stove-plate and shot iron, from 20 to 30 per cent.; on burnt iron, from 25 to 60 per cent., according to how badly the iron is burnt."

The same author gives the following data of a test-heat made in the foundry of the Jackson & Woodin Manufacturing Company, to ascertain the wastage of iron:

Heat melted March 24, 1876: Lump coal, 2,002 lbs.; No. 2 pig iron, 6,069 lbs.; limestone, 160 lbs.; castings, 5,029 lbs.; gates and scrap, 469 lbs.; cinder scrap, 287 lbs. Total iron put into the cupola, 6,069 lbs.; total iron out of the cupola, 5,785 lbs.: lost in melting, 284 lbs., or say 4.7 per cent., or 105 lbs. per 2,240 lbs.

Heat melted March 25, 1876: Lump coal, 2,002 lbs.; No. 2 pig iron, 6,069 lbs.; Kirk's chemical flux used; castings, 4,380 lbs.; gates and scrap, 1,036 lbs.; cinder scrap, 504 lbs. Total iron put into the cupola, 6,069 lbs.; total iron out of the cupola, 5,920 lbs.: lost in melting, 149 lbs., or say 2½ per cent., or 56 lbs. per 2,240 lbs.

*Charging the Cupola, and Casting.**—Supposing the cupola to be cool, but in good working order as to lining, tuyeres, etc., the falling iron door at the bottom, if the cupola is provided with one, must be closed, securely fastened in its place, and well covered with sand. Moulding sand is used when only a small quantity of iron is to be melted; if a large quantity of melted metal is required, a more refractory sand is desirable. A wood fire is then lit in the cupola, upon which coke, coal, or charcoal is placed, the tap-hole being left open to supply air to support the combustion, the tuyeres being also left open. The cupola is then filled with fuel, which is kept in brisk combustion. It requires several hours to heat the furnace for blast, which is not laid on until the flame appears on the top of the fuel. When the furnace is thoroughly heated, the nozzles are put in, and the fan or blower is put to work. Before putting on the blast, however, the large tap-hole must be closed with moulding sand, or good fire-proof clay and sand mixed, leaving a small hole at the bottom, which serves as the tap-hole for the iron. This should be about 2 inches diameter, and is formed by placing a tapered iron bar in the place where the hole is to be, ramming the sand tightly around it, and removing it as soon as the hole is properly and securely moulded. When the blast is put on it will drive a flame through the tap-hole, as well as out of the top of the cupola. The tap-hole is left open to dry the fresh loam and sand, and also so that its sides may be glazed or vitrified by the heat, so as to resist the friction of the tapping-bar; the heat also serves to glaze the lining of the cupola in those parts which have been mended with fire-clay since the last melting. When the cupola is intended to hold a large quantity of iron, the large tapping-hole should be covered with an iron plate, securely fastened to the iron casing, leaving only the small tap-hole open.

Commence charging iron as soon as the lower parts of the furnace show a white heat, which is best known by the color of the flame issuing from the tap-hole, it being at first a light blue, but afterward becoming of a whitish color. About ten minutes after charging the iron, the melted metal appears at the tap-hole, which must then be closed by a stopper made of loam, which has been worked by hand to a proper consistence; a round ball of this is placed on a disk of iron at the end of a wooden rod, and is forced into the tap-hole; this is also done when it is wished to stop a tapping out with the bott or bod stick, as it is called, but is then a more difficult operation, as the molten iron frequently squirts out past the bott stick while the men are trying to apply the plug. Pig iron is broken into pieces of from 10 to 15 inches in length before it is charged into the cupola. This is a very laborious operation, especially in the case of tough pig iron. The first breaking is generally accomplished by throwing the pig down heavily upon a piece of old iron fixed in the ground, after which it is broken up still smaller with a sledge-hammer. This work is now very often performed by an adaptation of Blake's or some other stone-crusher. From 10 to 12 lbs. of fuel are charged for every 100 lbs. of iron, but this quantity varies, depending much upon the nature of the fuel, of the iron to be melted, and upon the size and construction of the cupola. Along with the coke and iron, limestone must be put in, broken up into pieces about 2 inches cube, or oyster shells, in quantities varying from 2 to 5 per cent. according to the nature of the fuel and iron. Too much limestone, as well as too little, causes the iron to become white and lose some of its carbon, and in many cases its strength and softness are greatly impaired. The limestone, when used, is commonly introduced into the cupola after the first charge of metal. It is intended to act as a flux, and combine with any earthy matters that may be present in the metal and coke. With these it forms a glassy compound, and by this means the iron is freed from such impurities as it falls to the bottom. The slag, as it is termed, floats on the surface of the iron collected at the bottom, and frequently makes its appearance at the tuyeres in a solid state. The cupola should be kept full while in blast, or at least so long as iron is melted, by alternate charges of iron, fuel, and limestone. Fuel is generally put on first, then iron, and lastly the limestone, and the charging continued without intermission until all the iron required at that time is melted, when the charges are stopped. The blast is, however, kept on until all the iron has been tapped. As a matter of experience it has been found that the interior form of furnaces greatly affects the condition of the metal, and thus influences its applicability to certain uses. Thus cupolas which are larger in diameter at the bottom than at the top work hotter than those with parallel sides, and also last longer, as the melted iron, which is apt to cut the fire-brick, then sinks more through the materials in the body of the cupola than it does in cupolas with parallel sides. The amount of taper to be give to the lining depends upon the size of the cupola; a large one will bear more taper than a narrow one. If it is intended to melt different qualities of iron in the same heat, a thick layer of fuel should be placed between the various brands, so as to allow of the extraction of all the iron which was first charged before the second appears at the bottom. In such cases it is preferable first to melt the gray iron, or that iron which is to make

* From "A Practical Treatise on Casting and Founding," by N. E. Spretson.

soft castings, and white or hard iron afterward. When as much iron is melted as is required, the clay plug of the tap-hole is pierced by a sharp steel-pointed bar, or iron rod driven by a hammer, and the metal run into pots, or it is run directly into the mould by means of gutters moulded in the sand of the floor. After each successive tapping of the iron the tap-hole is closed, and more iron is allowed to accumulate in the bottom of the cupola.

When the work of the cupola is over, the workmen begin to clear it out. To this end they break down the temporary clay-work that narrows up the tapping-door to one small hole. Having cleared this away, a plate-iron fence is set up opposite the door, behind which the workman stands, and over which he shoots a long rod, kneed at the end, into the furnace, to loosen the contents, consisting of refuse coke and clay, and drag them out while yet hot; for, if suffered to remain until cold, they would be congealed into a compact mass. This operation is much more easily performed in cases where the cupola is built with a movable bottom.

*Charging the Reverberatory Furnace, and Casting.*—When a cast is to be made at a certain time, the reverberatory is heated for some hours previously by a brisk fire. When the furnace is white-hot the charging-door is opened, and the pig iron is placed in its proper position on the sole, due care being taken in stacking the metal as will be described, the most easily fusible portions being first charged and put at the bottom of the heap. The whole quantity of iron which it is desired to melt at one heat must be charged at the same time, as it is not considered advisable to add cold iron to that which is already melted. All the iron contained in a liquid form in the basin is to be tapped before any fresh pig can be charged. When all the iron contained in the furnace is melted, the tap-hole is opened with a sharp crowbar, and the liquid iron is either led into pots or directly into the mould. The tap-hole is stopped with damped sand, or a mixture of loam and coal-dust. When the furnace is charged with iron, all the openings and joints at the door and in the brickwork are to be cautiously stopped with moist loam, to prevent the access of any air upon the hearth. The fire-grate must also be well attended to, and kept well filled with coal, but not too high, so as to impair the draught of air through the fuel. The grate should be kept free from clinkers, and the formation of holes where unburnt air could enter the furnace must be prevented. The charging-door is generally a fire-block hung in an iron frame, which is raised and lowered by a lever, having a balance weight. All joints through which any cold air could enter the furnace must be covered with fire-clay or loam. The metal to be melted should be broken to a uniform size as far as possible; and on placing it in the furnace, the smallest pieces should be piled lowest, the larger ones on the top, as the heat of the flame is there more intense, which is what is required for the larger lumps of metal; and a similar plan must be adopted with regard to the melting of various qualities of metal, the most easily fusible being placed lowest in the furnace. Fuel should be fed in frequently, and it must be done quickly. When sufficient molten metal has accumulated in the pool of the furnace, it is tapped off. The chimney damper is first closed; the metal is then run into a ladle, or is run along plate-iron shoots covered with loam to the mould, being skimmed by the dam-plate and by men as it flows along, or into a pool in front of the furnace, the slag being removed before the metal passes into the moulds. The furnace is then cleared out, and any necessary repairs are executed before it is again charged. If the repairs have been considerable, it will be necessary to make the furnace white-hot before again charging it for use.

The reverberatory furnace is not only used for melting iron, but also for the melting of large quantities of brass, bronze, tin, lead, and other alloys and metals. Large bells, statues, machine frames, and similar objects, are cast from the reverberatory furnace. All metals, except very gray fusible iron, which may be cast from a pot, are to be run in dry sand ditches directly from the furnace into the mould. Furnaces for melting bronze should have a rather shorter flame-bed than is used for melting cast-iron.

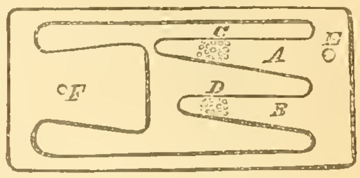
*Malleable Castings.*—The manufacture of what are known as malleable castings consists in obtaining a tough, soft, flexible material resembling wrought-iron, from white brittle castings, by the cementation process. The pig iron is melted in and run from clay crucibles into green or dry sand moulds, and where the articles are small snap-flasks are much used. The castings are removed from the moulds, and cleared from sand by brushing, by shaking in a rattle-barrel, or by similar means, and are then placed in cast-iron "saggers," with alternate layers of powdered red hematite ore, or with fine iron scales from the rolling-mills. The saggers are then placed in the annealing furnace, where they are exposed to a gradually increasing degree of heat until a full red heat is attained, after which they are allowed to cool down. The articles are then removed from the saggers, cleaned from the hematite powder, and, so far as rendering them "malleable" is concerned, the process is completed. The pig iron employed is almost invariably hematite; for large castings white hematite pig is selected, for small articles mottled pig. The best brands of cold-blast charcoal mottled irons, Nos. 4 and 5 Baltimore, or 5 and 6 Chicago, are preferable. It is essential that the pig shall be white or mottled, not gray; and it is not uncommon to melt up a quantity of scrap, such as wasters, gates, and fins of white iron.

*Compressed Castings.*—Steel is subjected to high pressure during casting by Whitworth's process. In casting hollow forms, rams are arranged to give a pressure to the melted metal in the mould. After this pressure has been applied for some time, and when the mass has become solidified, the core is withdrawn, and the metal is allowed to contract freely in cooling. In making articles of considerable length, the pressure is applied to the outer surface of the mould, and the latter is made in sections, between which dried loam or sand is placed, so as to allow the air to escape, and to admit of the sections being brought closer together. The pressure applied is about 2,500 tons. The moulds are strengthened by steel hoops, and the compressed steel is thus given a strength and homogeneousness unequaled by any other known metal.

In Bessemer's process the metal is poured into a revolving cylinder, whose rapid rotation causes it to collect on the inside of the same, when it is allowed to cool. It is then split open and rolled flat.

Warping of Castings.—Castings often warp during the cooling process, but in what direction this warping will take place depends in a great measure on the form of the casting, and the part of the mould at which the metal is run in. When a moulder knows from experience what part of a casting will warp, he can in many cases counteract it in the cooling process. For example: Suppose that, having cast a number of plates, such as shown in Fig. 741, he finds that the points of the tongues, *A* and *B*, always curl up in the mould to about a quarter of an inch too high. He will then pene the pattern so that the tongues stand a quarter of an inch too low, and thus save a great deal, if not all, of the pening. Another plan adopted by moulders to straighten castings is to uncover the parts that are apt to sink in the sand. If any part of a casting has the sand removed from its upper surface while it is still red-hot, that part cools the quickest and lifts up; and of this fact the moulder takes advantage, uncovering the part which experience has shown him requires to be lifted. The cause of the cooled part lifting appears to be as follows: The part cooled contracts the quickest; and to sink in the mould, it would require to compress the bed sand or else to raise the other part of the casting. The whole weight of the sand in the cope, as the top part of the mould is called, tends to keep the casting down; and when that weight is removed at any part by removing the sand, the contracted part naturally rises, because there is less resistance offered to its rising than there would be to its falling. In many cases this cooling process is aided by the application of water, which much increases its effect; and it is astonishing, under skillful manipulation, how much a plate or casting can be shaped at will, by water judiciously employed, without causing it to crack.

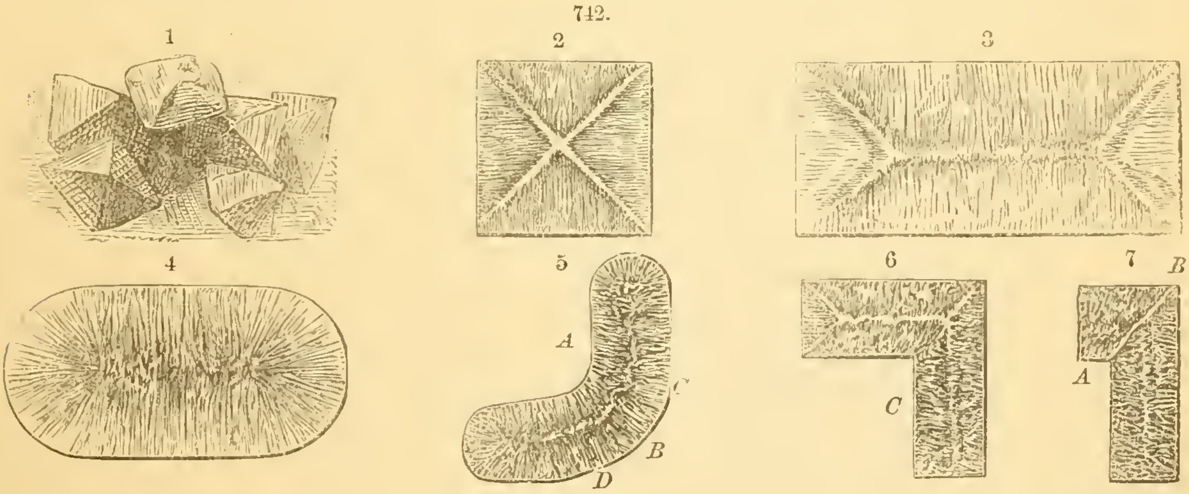
741.




It is obvious that this method of straightening by uncovering a casting is applicable mainly to thin or light castings. The uncovering of a casting while yet red-hot and resting in the mould is often resorted to to prevent the casting from cracking during the cooling process from the strains induced by the casting cooling in one part quicker than in another, the thick parts being uncovered to hasten the cooling, and thus equalize to some extent the contraction of the metal.

Iron poured into a mould, on changing from a liquid to a solid state, becomes a mass of crystals. These crystals are more or less irregular, but the form toward which they tend, and which they would assume if circumstances did not prevent, is that of a regular octahedron. This is an eight-sided figure, and may be imagined to have been formed out of two quadrilateral pyramids having their bases together. At 1, Fig. 742, is a group of crystals from a pig of iron, among

742.




which one has, by the aid of favorable circumstances, succeeded in attaining its natural form. In a perfect crystal of iron all the lines joining the opposite angles are of equal lengths, and at right angles to each other. These lines are called the axes of the crystals. The crystals assemble or group themselves in certain lines, in the direction in which the least pressure is exerted. When we define the direction of these lines as the direction of least pressure, we deal with pressure due to the mass itself. Heat leaves a mass of iron according to the same law; and therefore the lines of assemblage will be in the direction in which the heat leaves the body. This direction is always perpendicular to the cooling surface. We may then briefly state the law thus: The lines about which the crystals assemble are perpendicular to the surface of the casting as it lies in the mould. In Fig. 742, at 2, is a view of the end of a casting. This shows the assemblage lines, though the individual crystals are too small to be visible, the lines being perpendicular to the bounding surfaces. The attention should be particularly directed to the behavior of these lines at the corners of the castings. When two surfaces, as in this example, lie at an angle to each other, the systems of perpendiculars must meet in a plane diagonal to those surfaces. Some of the lines of each group run into the lines of the opposite group, so that in the diagonal plane the lines interlock, breaking up the natural order, and making very poor connection. We shall find in every such case that the diagonal is the weakest part, and that the casting will bear less strain there than through a part where the lines lie parallel to each other. In the figure which we are considering each corner has its weak line, meeting at the centre of the casting. In 3 we have a drawing of a flat bar, and in it we see the same diagonal lines of weakness. The pair of diagonals joining the corners nearest to each other are joined by a long line parallel to the two long surfaces. This line is also a line of weakness, as the lines in which the crystals assemble, in the systems belonging to each surface, begin at

the surface, and as the casting cools elongate toward the centre. When they meet in the middle they do not form continuous lines through from one surface to the other.

We see from the foregoing remarks that the strength of a casting is greatly impaired by the lines of weakness caused by angles; and now let us look for a means of remedy. Referring again to 2, and comparing it with 3 and 4, we see that by making the angles into curves the lines in which the crystals form themselves are all nearly parallel to each other; and the absence of abrupt changes of surface also avoids changes in crystalline arrangement, which will materially affect the strength of the casting. Comparing 7 with 5, it will be seen that there is much more metal through *A B* in 7 than there is through *A C* in 5; and yet the strength at the two places is nearly the same, and of course their change of form produces a corresponding derangement of crystalline structure; but the defect which in 7 was concentrated in the line *A B* is in 5 spread out between the points *C* and *D*, so that no single point is much weaker than a similar point beyond *C* or *D*.

SHRINKAGE STRAINS IN CASTINGS.*—*General Laws regarding Shrinkages.*—All castings will alter more or less in form if the surface is removed or cut away. This is partly due to the tension on the whole exterior of the casting during the process of cooling, and partly to the excess of tension upon those parts of the casting which take the most time to cool. The difference in the time required to cool the different parts of a casting depends upon their relative thicknesses, the freedom of access to the air, and the position in which the casting lies while losing its heat; nor is it practicable to so cool a casting as to make its surface-tension equal all over. If a casting is allowed to cool off in the mould, its surface-tension will be less than if extracted from the mould and cooled in the open air; while if, after the casting has become cold, it is reheated to a low red heat, the surface-tension will be considerably reduced, because in the first process of cooling the exterior metal, by cooling most rapidly, also attains its strength the soonest. It therefore offers a resistance to the set of the interior, and the latter conforms itself to some extent to the former. In reheating the casting, however, this condition is reversed, the exterior becoming heated, and therefore weakened in advance, so that the internal crystals are given more liberty to arrange themselves in their natural order.

The thickest part of a mass of molten metal always shrinks last; hence, if a casting be composed of irregular thickness, it will be liable to be broken by the forces contained within itself. It is, therefore, especially necessary that columns and castings, supporting or resisting great pressures, should be so designed as to prevent this great error. Mouldings on columns are often so badly designed with regard to this matter, that the columns are excessively weak where they should be the strongest. As a rule, mouldings should seldom be cast on a column, but rather bolted on. Much of the irregularity of flat castings and those of irregular shapes could be remedied by a proper attention to cooling the castings while in the mould. To be sure this is done to a certain extent, though few moulders know why they do so. They know that by removing the sand too soon from a particular casting it will straighten in the shrinking. This is but the result of experience, not of thought or any attempt to know why it so acts. It is useful to know, also, that all shrinkage takes place while the casting is changing from a red to a black heat.

*Solid Cylinders.*—In the case of a shaft, or other solid cylinder, it will be noticed that the surface of the casting at the ends will be slightly depressed. This is occasioned by the surface of the cylinder being cooled by the walls of the mould first, and setting, while the central portion yet remains fluid or soft. In a few moments more the central portion cools, and in shrinking draws in the ends of the cylinder, the outer crust acting as a prop or stay to the atoms of metal adjacent to it. If this theory be correct, the depression should take the form of an inverted cone, owing to the gradual checking of the shrinkage as it approaches the outer crust. In practice this will be found the case, the obtuseness of the angle being greater or less, according to the nature of the iron to shrink.

*Globes.*—The shrinkage strains within hollow, spherical shell-castings are similar to those in rings, they being no more in fact than rings continued about a central axis. In the case of solid globular castings, the heart or central point within will usually be found hollow or porous, owing to the following causes: The walls of the mould, cooling off the outer surface, cause it to set immediately; the interior, cooling from the exterior inward, endeavors to shrink away from the outer crust, which resists its so doing; hence, the interior is kept to a greater diameter than is natural, and, there being but so much metal in the entire mass, the atoms are drawn away from the central point toward all directions to supply the demand made by the metal in shrinking.

*Disks.*—In the case of flat, round disks or plates, they will usually be found hollow on the top side, although in some cases the hollow is on the bottom side. This is owing to the following causes: The top and bottom faces, together with the outside edge, become set first through contact with the mould, leaving the centre yet soft. When the centre shrinks a severe strain is put on the plate by an effort to reduce its diameter, which the outer edge resists. Now, if the cope be thin, the heat will radiate rapidly in that direction, causing the outer or top side to set first; the under side, setting later, will drag the top side over with it, causing it to round up on top and dish in the bottom. Or, if the pattern be not perfectly true in every direction, the strains first spoken of will cause any curved portion to become more exaggerated. If the pattern be perfectly true, cope and drag of the same thickness, and both rammed evenly, there is no reason why the plate should not come out perfectly true, the strains being all self-contained in the same plane and balanced. If the plate, however, have an ogee moulding projecting downward around the edge, it will likely be depressed on the top surface when cast. This is due to all the surfaces being set alike and at the same instant, excepting the metal within the corners, which, containing the most metal in a mass, will shrink last of all. When this does shrink, its tendency is to pull over the top side of the moulding toward the plate, which, being soft, although set, will be forced downward at the edges, giving a chance for the strains within the plate, as above described, to aid in the distortion.

* By Mr. Alfred E. Watkins.

*Round and Square Bars.*—These strains are similar in both, and are already treated of under solid cylinders. There is another feature, not before spoken of, which is rather curious. If two bars of the same dimensions and mixture of iron be heated to the same temperature, and the one allowed to cool in the mould, the other plunged while hot into water, the latter will be found to have shrunk the most. This is due to the particles above the surface having been enabled, by the softness of the interior metal, to get closer to each other than they could have done if the material had cooled slowly.

*Rectangular Tubes.*—These are usually cast with a core, which has a tendency to retain the shape of the casting; still the flat sides will show a tendency to bulge up slightly at the middle. This is due to much of the same causes as explained in the plate with the ogee mouldings: the outer surface is cooled instantly by the walls of the mould, and is set; the inner surface is not cooled quite so rapidly, owing to the core being of harder material and not so good a conductor of heat; when this does cool it will pull inward the outer skin of the casting, forming a slight curve; each side, acting for itself, will produce the same effects.

*Gutter or U-shaped Castings.*—These are usually made thinner at the edges than at the middle, because the pattern has been made with draught. When castings of this shape are taken from the mould, they will be found rounded over in the direction of their length, the legs being on the curved side. This is explained by the mould cooling and setting the legs first; then when the back or round shrinks, it pulls upward the two ends of the casting.

*Wedge-shaped Castings.*—In parallel castings of any length, having a cross-section similar to a wedge, or similar to a knife in paper-mill work, the thick side will invariably be found concave and the thin edge curved. This is due to the same causes as explained above. The thin edge is set as soon as cast; the thick edge, cooling later, shrinks and draws the ends of the casting upward, and with them the thin edge, which acts as a pillar to resist further shrinkage.

*Ribs on Plates.*—All ribs have a tendency to curve a plate if they be thicker or of the same thickness as the plate, owing to the fact that whatever shrinkage strain they possess is below the general plane of the shrinkage of the plate itself. If the ribs be thinner than the plate, they will cool first, and by resisting the shrinkage of the bottom of the plate cause it to curve upward, or "dish" on top.

*Table showing Shrinkage of Castings.*

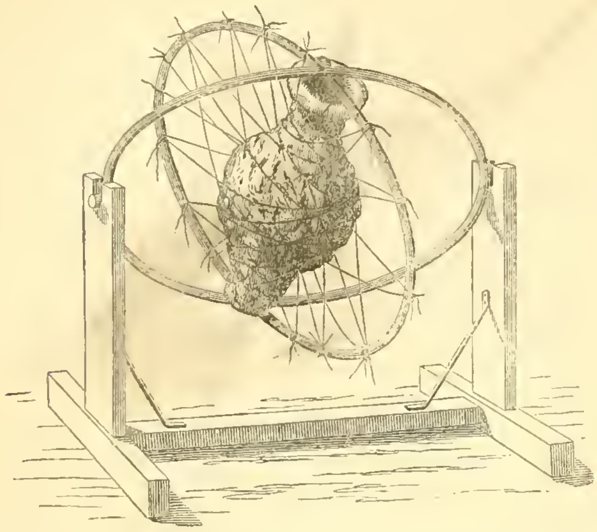
| | | |
|---|---|---|
| In locomotive cylinders | = | $\frac{1}{16}$ inch in a lineal foot. |
| In pipes | = | $\frac{1}{8}$ " " |
| Girders, beams, etc. | = | $\frac{1}{8}$ in 15 inches. |
| Engine-beams, connecting-rods | = | $\frac{1}{8}$ in 16 inches. |
| In large cylinders, say 70 inches diameter, 10 feet stroke, the contraction of diameter | = | $\frac{3}{8}$ at top. |
| Ditto | = | $\frac{1}{2}$ at bottom. |
| Ditto in length | = | $\frac{1}{8}$ in 16 inches. |
| In thin brass | = | $\frac{1}{8}$ in 9 inches. |
| In thick brass | = | $\frac{1}{8}$ in 10 inches. |
| In zinc | = | $\frac{5}{16}$ in a foot. |
| In lead | | from $\frac{1}{8}$ to $\frac{5}{16}$ in a foot. |
| In copper | = | $\frac{3}{16}$ in a foot. |
| In bismuth | = | $\frac{5}{32}$ " |
| In tin | | from $\frac{1}{12}$ to $\frac{1}{4}$ in a foot. |

The following is an easy rule to find approximate weight of castings: Thickness in $\frac{1}{8}$ inches $\times$ width in $\frac{1}{4}$ inches $\times$ length in feet = lbs. weight cast-iron. For lead, add one-half to the result; for brass, one-seventh; for copper, one-fifth.

Casting in Plaster.—In making a cast of a clay model of a bust, two methods may be pursued. The entire model may be covered over with the plaster mixture, by throwing it on in a creamy state with a cup or spoon, and lastly by spreading it on with the hands, until the proper thickness is attained to give sufficient strength; and then, after setting, the mould may be cut into sections with a very thin saw and carefully removed. The process more usually preferred is to apply the plaster in sections by the method of parting. A common way is to make only two sections, the smaller one embracing merely the crown of the head. This plan requires that the frame on which the bust was modeled shall be so constructed that it may be taken apart and removed by the hand, after the plaster is well set. After the mould has been carefully cleaned with water and a soft brush, the parts are put together and bound by a strong cord or rope, and the seams stopped on the external surface with cream of plaster. After this is set the mould is saturated with water. The bust is then cast by turning into the cavity successive batches of cream of plaster, at the same time turning the mould about in such a manner as to cause the plaster to run into all the lines and furrows, and to be deposited in sufficient thickness all over the interior surface. In this way a hollow cast is made without the use of a core. After the plaster is well set, the bust may be placed upon a table and the mould chipped off with a chisel and mallet. This is an operation which requires great care, and can only be done by an experienced hand, and by none so well as by the artist himself. The casting of a bust is rendered much easier by swinging the mould in a pair of strong, concentric iron rings, Fig. 743. This device allows it to be turned with ease in any position, greatly facilitates the operation, and diminishes the chances of making a defective cast. The plaster bust is used as a model by the marble-cutter in reproducing the work of the artist. When several copies in plaster are desired, it is used as a model on which to form a piece-mould, which may serve in producing an indefinite number of copies. A statue in plaster may be cast in a variety of ways, depending upon the purpose for which it is intended: whether to be preserved as a plaster statue, or copied in marble,

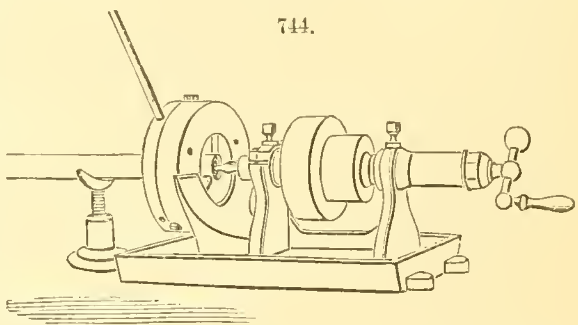
or to be used as a model from which to make a bronze cast. If it is to be preserved as a statue, it will be cast as nearly as may be in one piece; but if to be used as a model or pattern by the bronze-founder, it may either be taken in as many pieces as are to be made of the bronze casting, or it may be cast in one piece, or in as few as possible and then joined together, leaving the bronze-founder to make his selection of sections in which to take his loam mould.

743.



Casting of Bronze Statues.—Bronze containing 10 per cent. of tin requires a heat of about 2,000° F. to bring it to the proper degree of fluidity. It is considered rather a refractory metal, liable to fly, and requires skill and experience for its mastery. The pouring is done in the same manner as for bell-casting, and the same crucibles and furnaces are used. After the metal has cooled, the flask is removed, the loam knocked off, and the branches of metal which fill the spaces of the air-holes as well as those for pouring are cut off. When the statue is cast in sections, the edges are made somewhat thicker than the other parts, and lips are also provided, to meet in the interior so that they may be bolted together. The thickness of the edges is for supplying material for hammering them together till the seams are obliterated. The parts are usually immersed for a few hours in a weak pickle of acidulated water, for the purpose of loosening and aiding in the removal of silicious matter which has become incorporated with the surface of the bronze. All the sections are then bolted together, the edges smoothly hammered till the joints are perfect, all roughnesses filed away, and the whole surface chased with appropriate tools.

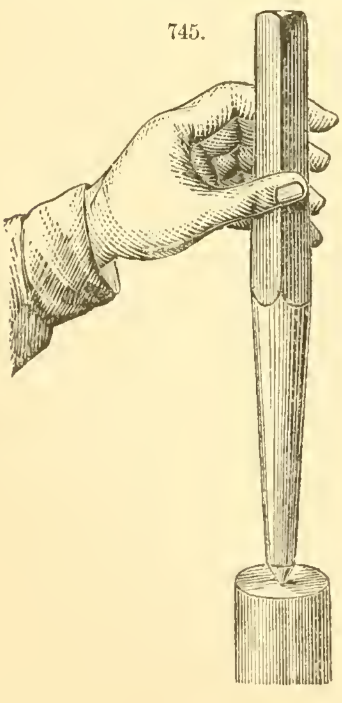
744.



CENTERING MACHINE. An apparatus, Fig. 744, used to centre, centre-drill, and countersink, at one and the same operation, bolts, spindles, shafts, etc., which are to be turned in the lathe. It is a great labor-saving tool, doing ten times as much work as can be done by hand. The chuck is a universal one, so that the work requires no setting. The combined drill and countersink is fed by the handle at the end of the running head. The drill should be run at about 300 revolutions per minute, and for use on wrought-iron and steel should, while cutting, be supplied freely with oil. J. R.

CENTRE-PUNCH. A tool employed to make the conical indentations necessary to receive the lathe-centres. The position for the indentation being marked, the centre-punch is placed as shown

745.



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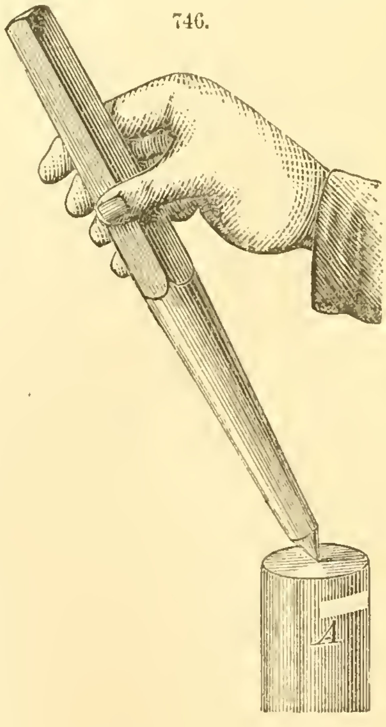

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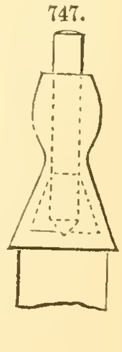


in Fig. 745, and its head is struck with a hammer. If the position of the indentation requires correcting, the centre-punch is canted to one side, as shown in Fig. 746, and then struck as before. In Fig. 747 the punch is shown partly encased in a device for use upon the ends of cylindrical work, and

designed to save marking the location for the indentation. The device consists of a round steel centre-punch, which slides freely in the stem of an inverted funnel or centering cone. To whatever distance the circular end of the work may enter this cone, the point of the punch will be always at its centre, which spot can be marked by giving the top of the punch a light blow with a hammer. J.R.

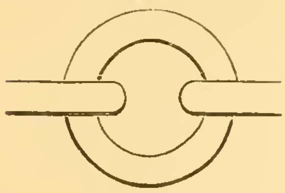
CENTRIFUGAL AND CENTRIPETAL FORCES. See Dynamics.

CENTRIFUGAL MACHINE. See Sugar-making Machines.

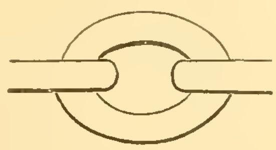
CENTRIFUGAL PUMP. See Pumps.

CHAIN. *Chain cables* are constructed either with open links, Figs. 748–750, or with stud-links,

748.



749.



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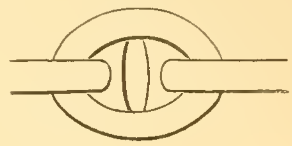

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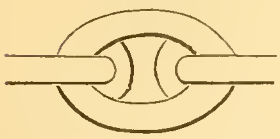

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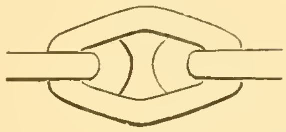

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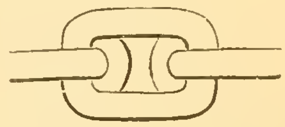


Figs. 751–753. The standard proportions of the links of chains, in terms of the diameter of the bar iron from which they are made, are as follows:

| | Extreme Length. | Extreme Width. |
|---|---|---|
| Stud-link | 6 diameters | 3.6 diameters. |
| Close link | 5 " | 3.5 " |
| Open link | 6 " | 3.5 " |
| Middle link | 5.5 " | 3.5 " |
| End links | 6.5 " | 4.1 " |

End links are the links which terminate each 15-fathom length of chain; they are made of thicker iron, generally 1.2 diameter of the common links. Fig. 748 is a circular link; 749, an oval link; 750, an oval stud-link with pointed stud; 751, an oval stud-link with broad-headed stud; 752, an obtuse-angled stud-link; 753, a parallel-sided stud-link.

The Admiralty test for the tensile strength of ordinary stud-link cables is at the rate of 630 lbs. per circular ⅛-inch section of one side of a link; equivalent to 22.92 tons per square inch of one side or to 11.46 tons per square inch of both sides taken together—just within the elastic limit. The weight of a link in similar cables increases as the cube of any lineal dimension, say the thickness; and the weight per yard increases as the square of the thickness of the chain. Hence the rule that the weight per yard of common stud-link chain cable equals in round numbers 27 times the square of the diameter. The weight of a bar of iron a yard long is 10 lbs. per square inch of section or 7.854 lbs. per circular inch; that is, a 1-inch round bar weighs 7.85 lbs. per yard, while a stud-chain cable of 1-inch iron weighs 26.9 lbs. per yard, or 3.42 times as much as a bar of the same size and length.

Very extended and elaborate investigations on the subject of the strength of chain cables were conducted (1878) by the U. S. Board Appointed to Test Iron, Steel, etc., the results of which show that, as applied to cables made from American bar iron, the Admiralty standard above noted is faulty in two important respects: 1. The stress prescribed by it for every size of cable is too great. 2. The stresses for the different sizes are unequal in their proportion to the strength of the links. It is pointed out that the stress for all sizes is based upon the assumption that the cable-bolts of all diameters possess a strength equal to 60,000 lbs. per square inch. Few bars of American iron are equal to this strength, and when they are, their cost precludes their use as cable iron; and, although this strength may be found in the small bars, it is not found in the large sizes of the same iron. Furthermore, it is urged that if the bars of all sizes did possess this strength, the "proof" is still too great, for it probably exceeds by a considerable amount the elastic limit of the links. The Board consequently undertook the preparation of a table by which cables could be proved without sustaining injury, basing this table on the principles that a proof-strain should not greatly exceed the elastic limit, and that the strength of a cable is equal only to that of its weakest link. In the preparation of this table it was first necessary to establish within reasonable limits the probable maximum and minimum strength of cables of various sizes, and the elastic limit of the links. Primarily, it was considered that the value of an iron for chain manufacture is not to be measured by the strength of the links, unless this strength is found to be uniformly maintained throughout a series of tests; for it was found that those irons which furnished the strongest links in nearly every case furnished also the weakest, their welding properties being generally defective; for, although the portions of the links which have not been subjected to forging are very strong, in each link there is a probable very weak spot caused by a defective weld. Comparative records were obtained of 210 sections of cables broken by tension, which were made of 15 different irons. Assuming that the utmost strength which can be found in a link is equal to 200 per cent. of that of the bar from which it was made, it was determined that bars of fairly good chain iron will produce links whose strength will be not less than 155 per cent. and not over 170 per cent., and that by a series of tests an average of not less than 163 per cent., made up of fairly uniform factors, should be expected. The Board therefore

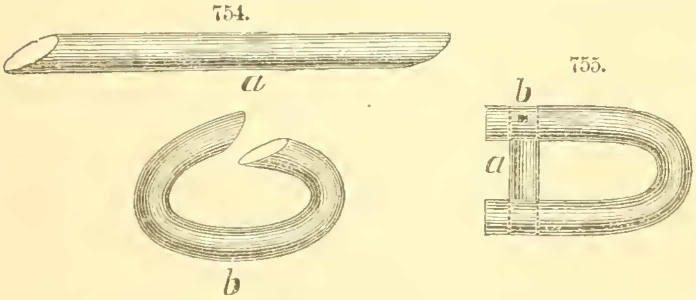
adopted for a standard of strength and welding qualities combined 170 per cent. of the strength of the bar for a maximum, 163 per cent. for an average, and 150 per cent. for a minimum. Experiments for determining suitable strength resulted in the conclusion that an iron is suitable which, as a 2-inch bar, has a strength of 50,000 lbs. per square inch, and that other irons whose variation from this strength does not exceed 5 per cent. are equally so. In determining the strength for the other sizes, it was found that the proportional strength of bars of the same material increases as the diameter decreases, and that the aggregate of the increase for the 16 sizes (measuring by sixteenths of an inch, between 2 inches and 1 inch) is from 4,000 to 6,000 lbs., produced by steps which are made more or less irregular by irregularities in heating the piles. The proving-strains, calculated upon the principles indicated, are as follows, being equal to 45.57 per cent. of the strength of the strongest and to 50 per cent. of that of the weakest links:

*Table showing Proving-Strains of Chain Cables.*

| Size. | Proving-strain. | | Size. | Proving-strain. | | Size. | Proving-strain. | |
|---|---|---|---|---|---|---|---|---|
| In. | Pounds. | Tons. | In | Pounds. | Tons. | In. | Pounds. | Tons. |
| 2 | 121,737 | $54\frac{777}{2240}$ | $1\frac{5}{8}$ | 82,956 | $37\frac{76}{2240}$ | $1\frac{1}{4}$ | 51,084 | $22\frac{1804}{2240}$ |
| $1\frac{15}{16}$ | 114,806 | $51\frac{566}{2240}$ | $1\frac{9}{16}$ | 77,159 | $34\frac{999}{2240}$ | $1\frac{3}{16}$ | 46,468 | $20\frac{1668}{2240}$ |
| $1\frac{7}{8}$ | 108,058 | $48\frac{530}{2240}$ | $1\frac{1}{2}$ | 71,550 | $31\frac{2110}{2240}$ | $1\frac{1}{8}$ | 42,053 | $18\frac{1733}{2240}$ |
| $1\frac{13}{16}$ | 101,499 | $45\frac{689}{2240}$ | $1\frac{7}{16}$ | 66,138 | $29\frac{1178}{2240}$ | $1\frac{1}{16}$ | 37,820 | $16\frac{1980}{2240}$ |
| $1\frac{3}{4}$ | 95,128 | $42\frac{1048}{2240}$ | $1\frac{3}{8}$ | 60,920 | $27\frac{440}{2240}$ | 1 | 33,840 | $15\frac{240}{2240}$ |
| $1\frac{11}{16}$ | 88,947 | $39\frac{1587}{2240}$ | $1\frac{5}{16}$ | 55,903 | $24\frac{2143}{2240}$ | | | |

*Manufacture of Cables.*—Several simple machines are used to manufacture chain cables. The successive operations are as follows: 1. Heating the round iron bars red-hot; 2. Cutting them of the required length, but with opposite bevels ($a$, Fig. 754); 3. Bending the rods around an elliptic mandrel. One end is placed against the side of a vertical mandrel and held there by a vise attached to the latter, and a lever provided with a projecting pin extending outside the rod is made to describe an ellipse, carrying the hot rod around the mandrel; this lever does not turn around a pin in the centre of the mandrel, but is attached to two slides which are forced to move in grooves occupying the position of the two axes of the mandrel; thus the pin of the lever describes an ellipse parallel to the periphery of the mandrel. 4. The new link ($b$, Fig. 754) is hooked to the last preceding link of the chain in process of making, and welded at a small forge. 5. While it is still hot, the cast-iron stay is introduced, and the link placed in a press, which compresses the two sides close upon the stay, at the same time that it makes these sides straighter; during this last operation an auxiliary straight rod is placed inside the end of the link, where the next link is to come, to prevent its closing. There are sometimes circumstances in which it is necessary to sever or slip (as it is called) a cable, or to shorten or lengthen it; this is done by means of a bolt and shackle substituted for a link every 15 fathoms, the portion of the cable between the shackles being called a length or "shot." The shackle is represented in Fig. 755, in which $a$ is the bolt, secured in its place by the pin $b$, which is again held in its place by having its head in a conical chamber filled with lead. One of the links next the shackle is heavier and larger than the others, for the purpose of receiving the shackle.

754. 755.

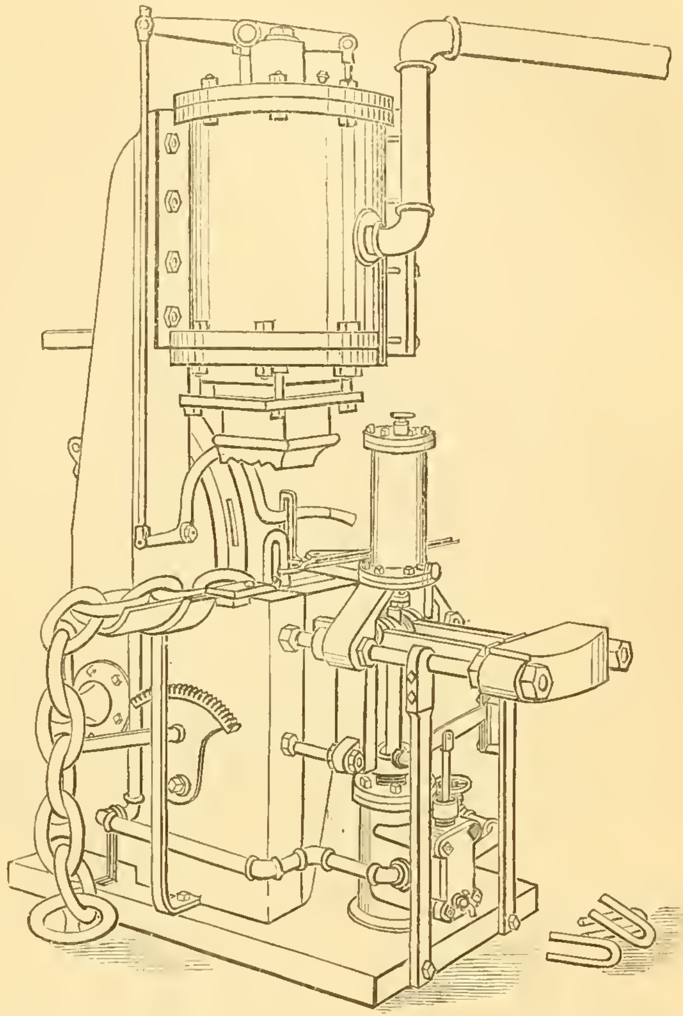



In Fig. 756 is represented a machine for making chain of 1¼-inch iron, in the links of which the weld is invisible. It is the invention of Mr. William Dennison, of East Cambridge, Mass.

The illustration shows the position of the chain in the machine while being manufactured. The anvil-block is a cubical mass of iron having a square recess from top to bottom, in which fits a vise or die-carrier. This is pivoted at the bottom, and is operated by toggle-jointed levers. This joint is connected to the vise at the top and to a cross-head or horizontal beam at the other end, and is elevated and depressed by the piston of a small steam-cylinder standing upright directly under the union of the levers. Inserted in the face of the vise is a die, cut to receive the half of one link in a vertical and the half of another in a horizontal position. A corresponding fixed half in the anvil completes the die. When closed the latter presents on its face two holes as far apart as the width of the link, and of a size to receive the iron to be welded. There is a channel passing between these holes for the reception of the last welded link. A trough or leader inclined and leading from the back of the machine, through a slot in the centre of the die, serves to convey the studs or bridges, and by a simple automatic movement a single one is fed to the die simultaneously with the closing of the vise. The small cylinder, with its piston-rod attached to the upper side of the toggle-joint, is filled with water, and serves only to steady the movement of opening and closing the vise. Rising from the back of the anvil-block is a heavy frame, supporting above a steam-cylinder of 13 inches diameter, with a square piston-rod, which serves as a hammer or press, the end of which is formed to correspond with the channel in the top of the die, and recessed to receive the link to be welded. There is another attachment, not shown in the engraving, a description of which is unnecessary, as it is merely an automatic appendage designed to turn and move the chain along as it is completed; when attached it is operated by the segmental gear shown on the side of the anvil-block. The links are prepared by another machine, which cuts and bends them to the form of an elongated U. The operation of the machine is as follows:

Convenient to the machine is a furnace, provided with more or less openings to receive the ends of the links, which, when properly heated, are inserted into the apertures of the closed die. Steam is then admitted, and the hammer is brought down, thus forcing, with a single blow, the link into the die and bringing the ends together, forming a butt weld. The vise is then opened by the small cylinder below, and the perfectly-formed link extracted. The vise is now closed, and the last-made link placed in the channel between the apertures of the closed die, when the next link is similarly proceeded with.

756.



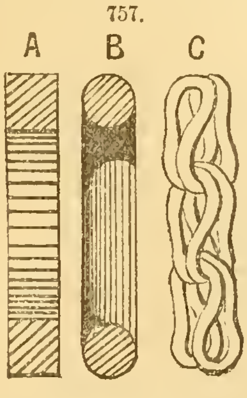
Weldless chain is made as follows: A hole is punched through a disk of the diameter of the flat ring shown at *A*, Fig. 757. The ring thus formed is spun on outside rolls until it acquires the round-bar section *B*, by which process also the direction of the fibre is modified. The ring is then drawn out into a long hook, which is bent to form a link, and is afterward interlocked with other links, as shown at *C*.

Flat-linked chains are made in the fly-press. The links are cut out in various forms, some of which are shown in Figs. 758 and 759, and in these holes are punched through which wire rivets or pins are inserted. Sometimes the succession of the links of the chain is one and two links alternately, or three and two, four and three, and so on up to eight and nine links, which is sometimes used. Probably the largest chain of this description ever made is that which secures the superstructure of the East River Bridge, New York, to its anchorages. (See Bridges.)

*Chains for Watches, Necklaces*, etc., are made in a variety of ways. When manufactured of steel, the slip is first perforated with rivet-holes for a number of links, by means of a punch in which two steel wires are inserted. The distance between the intended links is obtained (somewhat as in file-cutting) by resting the burrs of the two previous holes against the sharp edge of the bolster. The links are afterward cut out by a punch and bolster of minute size. The punch has two pins inserted at the distance of the rivet-holes, to serve as guides, which enter the link-holes. When the links measure from a quarter to a half inch in length, the press is worked by a screw; otherwise the punches are carried in a heavy block, in which is a square bar, struck by a spring hammer.

Chains of precious metal are commonly formed of links punched into shape from sheet metal, or else of wire bent into the desired forms. When the links are punched out solid, every other one is cut by a fine saw to receive the adjacent links, after the insertion of which the slit is soldered.

757.

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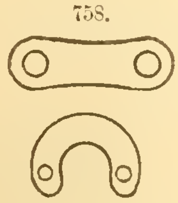

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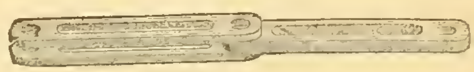

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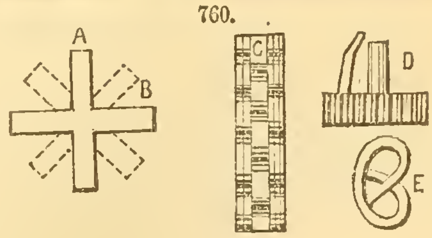



Ornamental chains, such as are usually thinly plated with gold and sold by dealers in cheap jewelry are made of pieces of brass wire and rings and bits of metal, rolled in various fancy forms, which are afterward brazed together.

Two ingenious machines for making fine chain were exhibited at the Paris Exposition of 1878. The essential principles of these will be understood from Fig. 760. For producing closely woven round chain, such as is used for necklaces (*C*, Fig. 760), an apparatus consisting of a series of star-

shaped punches is employed. On the strip of metal being fed under a punch, a piece of the desired shape is cut out and forced down into a holder below. The holder is then so moved as to turn the blank horizontally over a quarter revolution, as from *A* to *B*, Fig. 760. Meanwhile a second piece *A* is stamped out and forced down upon the turned piece *B*, so that the arms of *B* thus come into the spaces between the arms of *A*. The construction of the punch is such that the centres of the blanks are depressed and the arms raised, so that when two blanks are superposed as already described the arms interlock, those of the under blank *B* coming up between those of the upper blank *A*. It remains to bend the arms entirely over, which is done by ingenious contrivances—which need not here be explained—to unite the two blanks. A third blank is then placed upon *A*, and the arms of the latter are brought over this; and thus the operation is continued, the result being a chain which closely resembles a flexible bar of metal. The machine produces about 45 feet of this chain per hour, with 6 punches in operation.

The second machine makes twisted links of fine wire of the form shown at *E*, Fig. 760. The wire is fed forward horizontally by suitable devices, and is grasped near its end between rods, the extremities of which meet at an angle. Near the ends of the rods are placed cog-wheels *D*, which carry bent arms as shown. By means of a sliding carriage, these cogs are rotated after the wire is grasped. The result of this is that each arm bends the wire on opposite sides of the holding-rods in different directions, the wire meanwhile being cut off from the main portion by a descending blade. This produces the link above shown. A hooked needle now descends from above and catches the link as the rods release it. The protruding end of the wire then passes through the link thus formed, and another link is bent as before described, the operation thus continuing indefinitely.

CHAMFERING. See Barrel-making Machinery, and Carpentry.

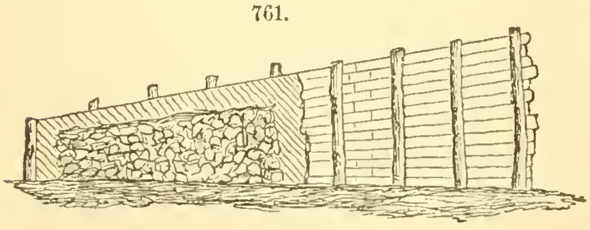
CHANGE-WHEELS. See Lathe Tools, Metal-working.

CHARCOAL. The general principles of charring wood and coking coal are the same, viz.: the expulsion by heat, without contact of air, of the volatile constituents of the fuel. These constituents go off in part as gases, containing more or less carbon, and in part as new combinations which are still liquid at a high temperature, as acetic acid, tar, etc. The details of these operations may be grouped into two great classes: 1, where the carbonization is effected in a permanent, air-excluding *oven;* 2, where it is done in *clamps*, or *kilns*, or *heaps*. In the general aspect of carbonization, the means employed would have to be antecedently classed according as use may be made, first, of other fuel than that to be carbonized to generate the requisite heat, or secondly, of a part of the mass itself for the charring of the other part. The type of the first system is seen generally in all the apparatus where other products than carbon are sought to be collected, and where the coke or charcoal is incidental to the operation; as in gas retorts, or the cylinders for pyroligneous acid or wood vinegar. Although a system like these might in some localities, where fuel was abundant or in different qualities, be advantageously introduced, there is probably no establishment where it is resorted to for the production of charcoal alone; and the other classification, of *ovens* or *kilns*, remains as the only one that need be discussed here.

The relative advantages of ovens and kilns can only be ascertained by a comparison of their products in quantity and quality. With respect to the first element, *quantity*, it may be assumed (though it is not universally admitted) that ovens produce a greater quantity by weight of carbon from the raw material. Hardly any collier can claim a yield of more than 20 per cent. of charcoal from heaps; while the best ovens, with perhaps less trouble, though not less expense in individual cases, will give about 25 per cent. Again, in the assemblage of cases, the expense for ovens is probably less, being less exposed to accidents from weather, neglect, etc., which sometimes result in the combustion of an entire kiln. With respect to *quality* of product, the evidence is less decisive. It would seem in theory that the oven, producing a greater weight of carbon, ought also to produce a heavier material *per se*. But such is not always, nor even generally, the case; and where the oven charcoal or coke is of the highest specific gravity (and the economy of a high specific gravity is in general undoubted), yet from some cause, such as a peculiar arrangement or disarrangement of fibres, it is not found to develop so much heat as that prepared in kilns. Generally speaking, the advantages of ovens over heaps or pits are not so great as is often supposed; and, as a rule, it may be asserted that no charcoal made under an immovable covering is so strong as that made under a movable one. The only real advantage of the oven arises from its being less subject to the changes of the atmosphere than the pit.

*Charring of wood* is still practised in Austria after methods which seem to have originated in the period of Roman domination, for the manufacture of the celebrated Norican iron. These may be

761.



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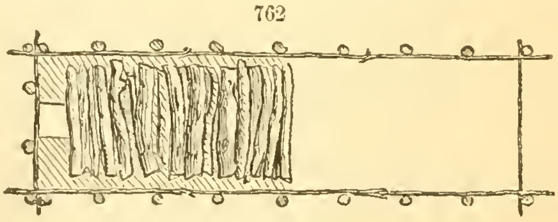


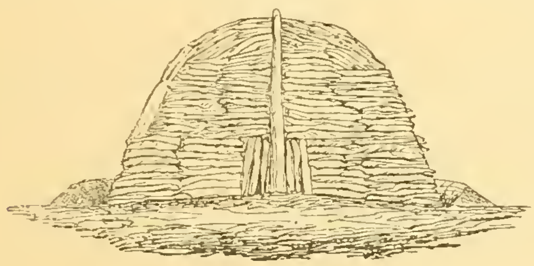
denominated charring *in heaps* (Germ. *haufen*) or *clamps*, and will be understood from the accompanying sketches, of which Fig. 761 shows a side-view, and Fig. 762 a ground-plan of the arrangement. The ground for this may be either leveled or sloped. In either case, pipes are sometimes, but rarely, laid in the upper parts of the clamp, to carry off some of the liquid products. The length of the clamp (and, of course, the number of posts) is arbitrary—generally from 40 to 50 feet; the width depends upon the length of the logs, which, being ordinarily 4 feet, and being laid

in a double row, with a very small space, to the casing of the sides, will make the width very nearly 9 feet across from post to post. In Fig. 762 the logs are given as if in but one length, which can very well be if the sticks are light. The casing may be of plank, slabs, or split cord-wood. The ground is well pounded, and, if in an old burning, with charcoal and dust. The logs are then piled, beginning from the upper part, to within a few inches of the top of the casing. Then it is covered with chips, twigs, and leaves, and finally with sand or (better) dust, which material is also filled in against the casing, to protect it from fire. After all this is ready, fire is put in at the lower end, and some of the dust is removed from the upper end to make a draught. Draught-holes are also opened at discretion in the sides of the casing. When the smoke comes out where the dust is removed, it is necessary to throw it on again, and open elsewhere with caution. In this manner the fire is led on till the heat has charred the whole. The peculiar advantage of this method is supposed to be that, with a clamp say of 50 feet, charcoal may be drawn from the lower end after the fire has progressed about 10 feet, which it will do ordinarily in twenty-four hours. This is still further helped by making it on sloping ground. If well packed, a clamp of 50 by 9 feet, 6 feet high at the head and 3 feet at the foot, will hold about 15 cords.

Another method, more extensively and commonly practised, is that of *kilns* (Germ. *meiler*, Fr. *meules*). These kilns are of two kinds, *standing* and *lying*, the wood standing on its end in the one, and lying on its side in the other, as shown in Fig. 763 and 764.

The circle to be leveled and pounded down for a kiln of this sort will be from 40 to 50 feet in diameter; the driest ground must be selected for the purpose, and a place sheltered from winds. The best period for burning in America is from the middle of May until the middle of August; and then again in October and November, during the season known as the Indian summer. Wood which has been felled, and lopped, and barked in December and January, will be sufficiently seasoned to char in the autumn following. After the logs have been arranged, as in the figures, around the three long stakes of ten or twelve feet in length (which are to serve as a chimney), and piled as evenly and compactly as possible, the whole pile must be covered to keep out the air. A site for a coaling improves

763.



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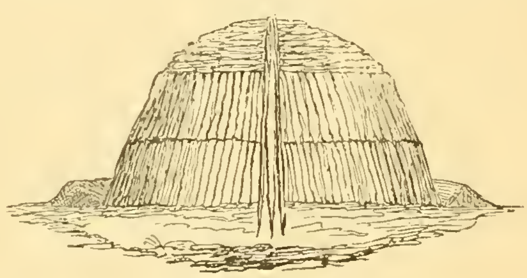
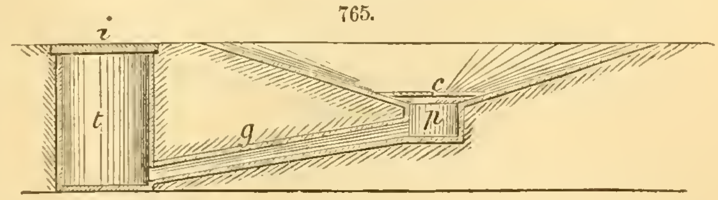


by use, for the charcoal and loam get trodden and mixed together, forming the best material for the covering. On entirely new ground use must be had of sod. When covered, fire is applied, either through the top and suffered to fall through to the centre, where provision has been made of some light wood to catch readily, or through a horizontal flue left along the ground, which is closed at its entrance as soon as the fire has taken. For the first twelve hours the kiln must be closely watched, and, therefore, it is usual to light at daybreak. At the end of that period, or a little longer, according to the kind of wood, its state of seasoning, and the skill of the collier, the fire will have taken sufficiently, and the top may be covered in with dust and loam. From that time, it is better that the operation should proceed as gradually and slowly as possible. In three or four days the cover begins to shrink and fall in, and fresh watchfulness is required to stop every opening thus made, and even new ones are made to effect an equable distribution of heat. These are points that cannot be taught by talking; they are lessons of experience and observation. When the cover sinks gradually, and the smoke grows less and less, regularly, the work is known to be going on well. Expert colliers find indications of the process in the *color* of the vapor and smoke, which varies at different stages. After all smoke has ceased, the kiln is entirely and thickly covered, and left for four or five days, less or more according to its size, *to cool*. The coal is begun to be drawn from the foot, but cautiously at first, until it is found to be too cool to re-ignite upon admission of air. If so, the drawing may be continued all round for coal that is wanted, peeling it off, as it were, like an onion; the whole contents may be hauled off to store, or it may be left (covered up again) to be resorted to when wanted. In proportion as the kiln is well piled, flues in various places are unnecessary. It sometimes happens that the fire takes in particular parts, or does not take at all. In this last event, the advantage of a horizontal firing flue is tested. A kiln of ordinary size, of this kind, holds about 30 cords; the largest contain 50 cords.

When the circumstances are such as to render it likely that the same charring-ground will be used for a considerable period, it is worth while to adapt to it some permanent accessions, as indicated in Fig. 765; which represents the section of a basin laid in dry brick, to serve as the ground of the kiln. This basin has a pit at $p$, with a cast-iron cover $c$, to keep ashes out, and a gutter, $g$, communicating with the tank $t$, which receives the liquid products of carbonization. With resinous wood, these products are advantageously removed as soon as possible from the charcoal, and are valuable when caught. The tank has a lid, $i$, which must be laid over it and luted when the kiln is fired.

765.

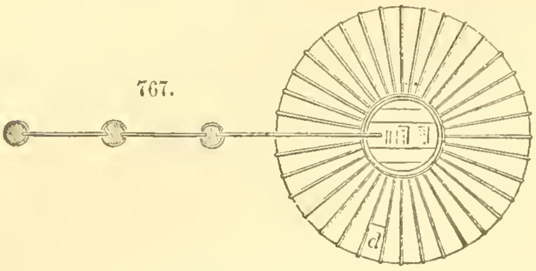



Midway between ovens and kilns comes the shroud or *abri* of Foucauld; of which a side-view is

shown in Fig. 766, and an orthographic one in Fig. 767. It consists, in fact, of a series of trapezial ladders, made of light frames, and capable of enclosing a circle at the base of 30 feet, at the top of 10

766.


767.

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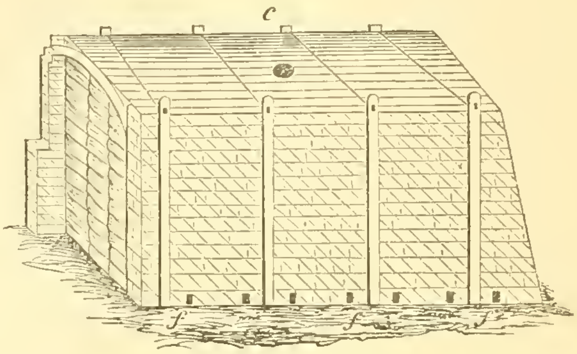



feet, with an elevation of 8 or 9 feet. The sides of these frames are furnished with mortises or lugs, by which two adjoining strings can be keyed together with wooden bolts. The top is a flat cover of scantling, with traps that can be opened or shut for the passage of air, and also for that of a conduit made of three pieces of light plank, for the condensation of gaseous products. The effect of these ladders is to allow of a better packing (and, as it were, thatching) of the ordinary loam covering of kilns. Fire is applied, and air furnished at first through the door *d*, left in one of the ladders. The charcoal furnished by this method is said to be of superior quality; its yield is stated at 24 per cent. of the wood, with 20 per cent. besides in crude pyroligneous acid. This yield of charcoal is about one-fifth more than from the kilns that have been described.

Of *ovens* there is a great variety of form; but as the most of them are embarrassed with apparatus for collecting other products besides charcoal, they are more connected with distillation than carbonization for the manufacture of iron. Only one, of the most simple and economical form, and yet yielding good results, will be described. A portion of it is shown in Fig. 768, which is supposed to give a tolerably clear idea of the plan. The building from which this is taken is about 50 feet long, 12 feet wide in the clear, and 12 feet high, and will hold, well packed, about 60 cords, a quantity that has been found to present the maximum of convenience and economy. *c* shows the chimney-hole in the centre for firing, *f f* flue-holes for the draught, of which there are others on top which cannot be seen. At the ends there is a small door for charging and drawing. The stays are of cast-iron or wood, the horizontal binders on top of bar-iron. Wooden scantling was first used for both these, but it is neither so safe nor so strong. The arch which is sprung for the top is low, but yet, when the fire is in, there is considerable thrust against the walls. These walls are 1½ brick, and must be well laid and joined. As the acetous products in the oven are apt to attack the lime, asphalt, or a bituminous cement made of coal-tar and loam, is used instead of ordinary mortar. Coal-tar is also advantageously used for coating the outside. The wood is piled lying, as is seen in the figure. Under the chimney-hole, a chimney (so to call it) is left in the pile, at the bottom of which the fire is placed. The wood may be kindled through the draught-holes or at the doors, but less economically. When the fire is first started all air-holes are shut; when it is fairly caught the chimney may be filled up with dry wood, the hole closed, but not tightly, and air-holes opened at the ends. This will happen in seven or eight hours. The operation must now be watched, and by the emission of smoke and vapor through the air-holes, a judgment may be formed as to where they should be shut and where opened. In 45 to 50 hours the whole oven will have been heated; all openings are then closed and luted, and the concern left for three or four days to cool. On the fourth or fifth day at latest the coal should be fit to be drawn.

To what has been said, may be added some generalities as to the choice of wood and quality of the charcoal. The denser woods are to be preferred, because, other things equal, they afford a denser and harder charcoal. Decayed or doted wood will not yield a good article; and charcoal from green wood is more light, more friable, and less calorific than from dry, besides being less economical in the manufacture. The trees should be felled when the sap is down, i. e. in the winter, from December to February. Small timber is in general, and young timber always, worse than that which has attained a larger and more mature growth. Yet *very* old wood is not so good, because there is always more or less decomposition of the fibre. Branches of trees give less and a lighter charcoal than the boles, and the best of all is furnished by that part of the trunk and roots nearest the ground. In the ordinary felling of trees this part is all lost. Hence it would be better for the purpose (and the land would be left in a better state) to extract the trees at once by the roots, as is very easy, and then saw the timber instead of cutting. Heavy charcoal produces more heat, but its *reducing* effect is not in every case in proportion. There are some mines with which lighter charcoal acts better; but that it should be *hard* is an important characteristic universally. Charcoal just from the kiln burns quicker and produces less heat than that which has been kept some time in store, yet very old charcoal is admitted to be less valuable than what has not passed over one season. To what this is owing is not clear, for the affinity of the material for moisture is exercised very promptly, and after the first 24 hours, in an ordinary atmosphere and with reasonable precautions, it does not materially increase in weight. It is better to keep charcoal in store than to leave it stored in the kiln. After it has grown cool enough to handle, the sooner it is made quite cold the better; all gradual expulsion of heat, such as occurs in a kiln, is at an expense of carbon. With ovens this caution is unnecessary, for the circumstances there always compel removal of the charcoal as soon as manufactured. The product in charcoal ranges from 18 to 22 per cent. in kilns, and from 20 to 25 per cent. in ovens. By volume a cord of wood, 128 cubic feet,

well corded, ought to give, at a mean, 40 bushels of charcoal. The price depends, of course, upon the value of labor in every locality, and the distance of hauling. The chopping of a cord of wood is equivalent to about one-third of a day's labor in the abstract, and the coaling of it in kilns or clamps afterward to about half a day. The computations of the charcoal-burner are usually made upon the 100 bushels of charcoal delivered. Coaling in ovens, although in fact less laborious and demanding less experience, requires more tact, and wages there are generally higher.

For *peat charcoal*, see PEAT MACHINERY.

*Works for Reference.*—"A Handbook for Charcoal-Burners," Svedelius (translated by Anderson), New York, 1875; Percy's "Metallurgy" ("Fuel"), London, 1875. Very complete references to all the literature on the subject will be found in the latter work.

CHASER. See LATHE TOOLS, SCREW-CUTTING.

CHEESE-MAKING. See DAIRY APPARATUS.

CHEMICAL FIRE ENGINE. See FIRE-EXTINGUISHER.

CHIMNEY. The functions of a chimney are to cause a sufficient flow of air through a furnace to maintain combustion, and to discharge the products of the latter at such an elevation above the ground that the adjacent atmosphere may not be rendered unfit for respiration. It is chiefly necessary that a sufficient height be given to the chimney, and that an appropriate material be chosen for its construction. If the chimney cannot be made high enough, then the necessary draught must be produced by special means. In locomotives, the exhaust steam is therefore allowed to escape into the stack (see LOCOMOTIVE), and in other cases ventilators or blowers (see BLOWERS) are employed, which either blow the air beneath the grate or suck it out of the flues.

Chimneys are constructed of masonry or of metal. In the first case bricks are preferably used, and in the second sheet-iron is employed. The external form of brick chimneys is generally quadrangular or octangular, while metal chimneys have always the shape of a truncated cone. Usually an exterior batter of 0.015 to 0.025 per foot height is given to chimneys, while the walls have the usual width of the bricks (6 inches) above, and at the bottom they have a thickness of double or three times this width. As to the height and diameter of chimneys, the one dimension depends upon the other. The higher a chimney is built, the more draught it gives, and the smaller therefore its diameter needs to be for the removal of a given quantity of smoke. Besides this, the dimensions also depend upon the temperature of the smoke which enters the chimney; and for an equal quantity of smoke the dimensions must be so much larger, the less the temperature of the smoke which is to be removed. According to this, an economical use of heat requires high and wide chimneys. The usual height of chimneys is from 60 to 120 feet; we rarely find them 40 feet or less, and chimneys of 300 or 400 feet are seldom constructed. It is a practical rule to give the chimney the same cross-section as the flues. It is very necessary to place chimneys upon a solid base, as the least sinking may cause damage or even destruction.

An exterior view and cross-section of an octagonal chimney of bricks is given in Figs. 769 and 770, and an exterior view of a metal chimney is shown in Fig. 771.* In the first, *A* is the foundation, *B* the termination of the flues or smoke-box, *C* the cast-iron cap of the chimney, and *D* a staircase which leads to an opening for cleaning the flues and chimney. To prevent the current of smoke from meeting resistance at its entrance into the chimney, the union between the flue and smoke-box must be rounded off. In Fig. 771, *A* represents the foundation, constructed of bricks and resting on a solid base. *D D* are anchor-screws, which firmly connect the base of the chimney, by means of a plate *E E*, with the foundation, and *G* is a pulley fixed below the head of the chimney *F*, over which passes a chain by means of which a man can be pulled up for the purpose of cleaning and painting the chimney. *B* is the termination of the smoke-box, and *H* the opening for cleaning. To prevent the overturning of such a chimney in a storm, not infrequently wires, stays, or cables are drawn in an inclined direction from the chimney to the ground and anchored.

With steam-boilers, the heat of the air in the chimney should not exceed 600°, and ordinary stock bricks will stand that temperature well; but with reverberatory and other brick furnaces the air is at a temperature of about 2,250°, and for such cases the chimney should be lined with fire-brick throughout; and as the adhesion of mortar is soon destroyed with such high temperatures, there should be wrought-iron bands round the outside at regular distances from top to bottom. In ordinary chimneys hoop iron should be built into the brickwork every few courses to form a bond; and a lightning conductor should not be omitted.

*Theory of Chimney Draught.*—The draught of a chimney is caused by a difference of pressure at the base of the chimney acting in an upward direction, due to the difference between the weight of the heated gases in the chimney and a column of the external air of equal height and cross-section. This difference of pressure is easily found. If we take a unit of area of the cross-section—one square foot, for example—the weight of the column of external air will be the height of the chimney multiplied by the density of the external air, and the weight of the column of heated gases of equal height will be equal to the height of the chimney multiplied by the density of the heated gases. If $h$ be the height of the chimney, $y$ the density of the external air, and $y'$ the density of the smoke column, the difference of pressure referred to will be, in algebraic symbols:

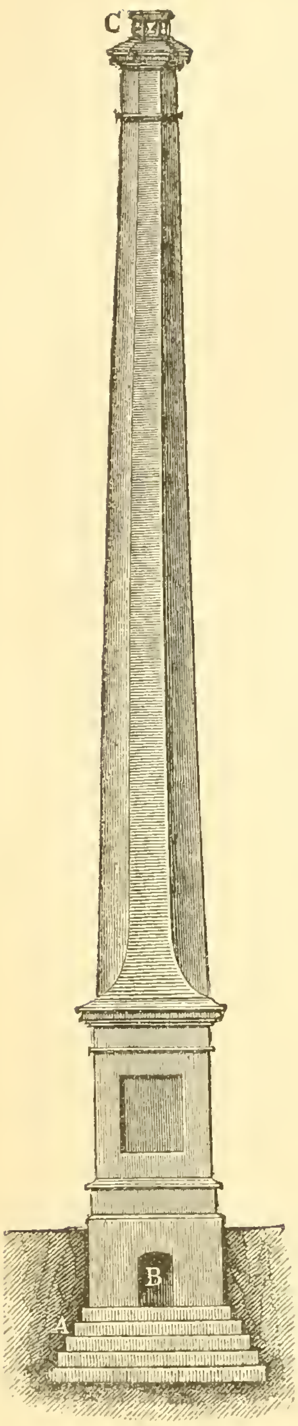
$$(1.)\quad p = hy - hy' = h\,(y - y').$$

This unbalanced pressure acts as a motive force to drive the heated gases through the chimney and out at the top. In order to find what height of column of the external air would produce this pressure, acting simply by its weight, we have to divide the pressure by the density of the external air, and shall have

$$(2.)\quad \frac{p}{y} = h\left(\frac{y - y'}{y}\right).$$

* From Weisbach's "Mechanics of Engineering," vol. ii.

769.

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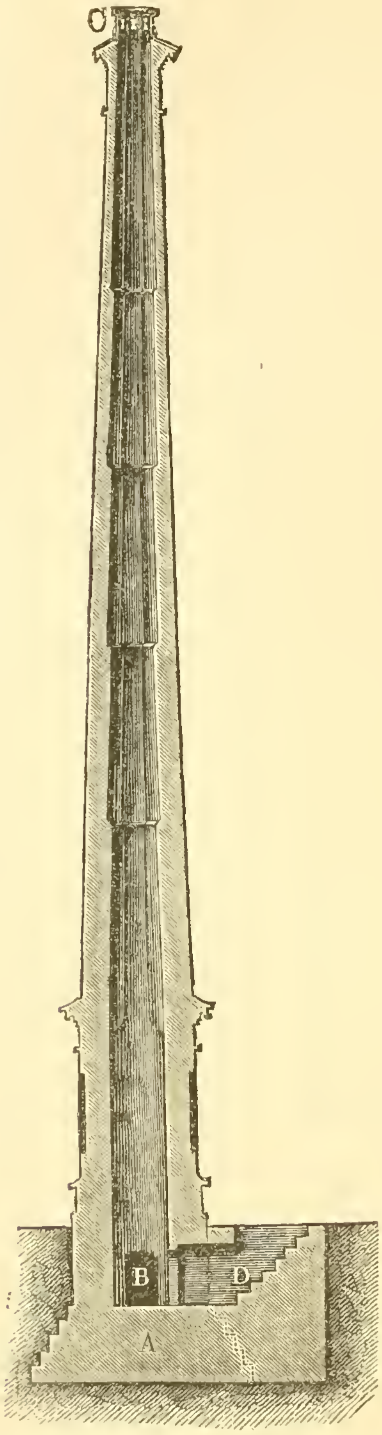


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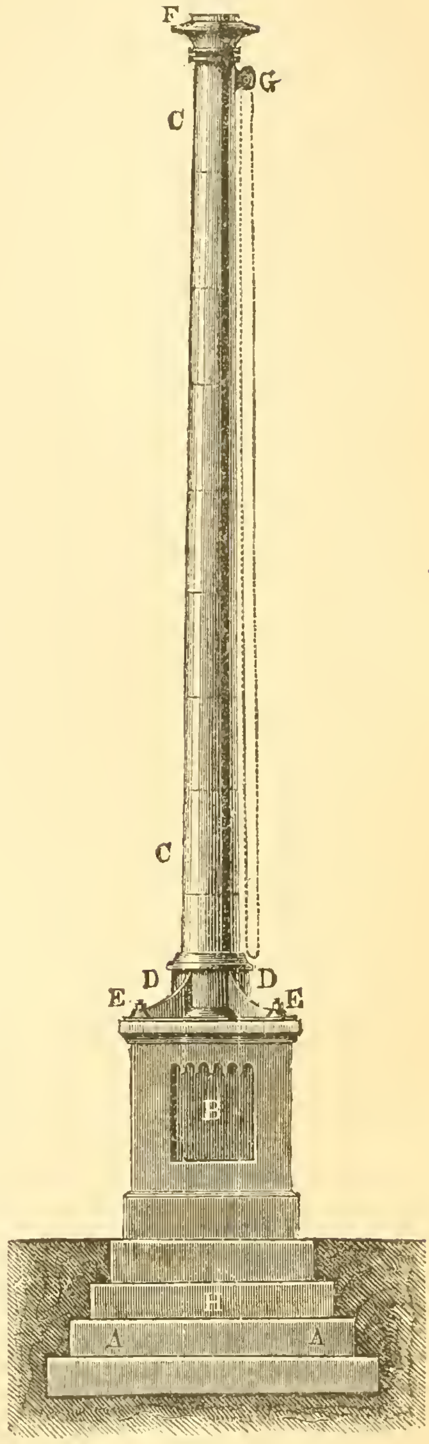



It is a well-known law of dynamics that the theoretical velocity ($V$) with which the air would enter the chimney if there were no resistance would be found by the equation,

$$(3.)\quad h\left(\frac{y-y'}{y}\right)=\frac{V^2}{2g}.$$

From which we have

$$(4.)\quad V=\sqrt{2gh\times\frac{y-y'}{y}}.$$

The velocity determined from this formula is not, however, that with which the external air will enter the chimney. Resistance is offered to the passage of the air through the grate, through the bed of fuel, and through the flues and chimney. These resistances do not admit of theoretical determination, and can only be found by direct experiment. They are proportional to the square of the actual velocity, and depend on the diameter and length of the flues and chimney, the thickness of the bed of fuel, and the state of division of the latter. Weisbach gives the formula, based partly on the observation of Péclet:

$$V=0.477\sqrt{\frac{(t_1-t)\,hd}{30d+0.05h}}\ \text{feet};$$

in which $t$ is the mean outer and $t_i$ the mean inner temperature, or that of the smoke; $h$ as before representing the height and $d$ the breadth of the chimney.

The values of the velocity of access of air found by Péclet for heights of 32.8, 65.6, and 98.4 feet were 5.1 feet, 8 feet, and 9.18 feet per second, or 18,360, 28,800, and 32,948 feet per hour. These velocities, divided by the number of cubic feet of air required to burn one pound of fuel, will give the quantity of fuel burned per hour for each square foot of section of chimney, the section being supposed equal to the free surface of the grate. In the ordinary process of combustion in a grate, it is apparent that some of the air which enters must escape contact with the fuel and enter the chimney as air. This, according to Morin and Tresca, equals 1.75 of the amount actually required for combustion. According to this result, the quantity of air actually drawn into the furnace for each pound of ordinary coal burned will be about 250 cubic feet. (See Boilers.) The consumption of fuel per square foot of chimney will then be, for the heights above given—

| | | | |
|---|---|---|---|
| Heights .................................... | 32.8 | 65.6 | 98.4 |
| Pounds.................................... | 73.4 | 115.1 | 137.8 |

Assuming that each square foot of section of chimney corresponds to 8 square feet of grate surface, the above figures will give, for the rate of combustion on each square foot of grate surface, 9.2, 14.8, and 17.2 lbs. Table I. is taken from "Heat as a Source of Power," by William P. Trowbridge (New York, 1874), from which also the above discussion has mainly been extracted.

Table I., *showing Heights of Chimneys for producing Rates of Combustion per Square Foot of Area of Section of Chimney.*

| HEIGHTS IN FEET. | Pounds of Coal burned per Hour, per Square Foot of Section of Chimney. | Pounds of Coal burned per Hour, per Square Foot of Grate, the Ratio of Grate to Section of Chimney being as 8 to 1. | HEIGHTS IN FEET. | Pounds of Coal burned per Hour, per Square Foot of Section of Chimney. | Pounds of Coal burned per Hour, per Square Foot of Grate, the Ratio of Grate to Section of Chimney being as 8 to 1. |
|---|---|---|---|---|---|
| 20 | 60 | 7.5 | 70 | 126 | 15.8 |
| 25 | 68 | 8.5 | 75 | 131 | 16.4 |
| 30 | 76 | 9.5 | 80 | 135 | 16.9 |
| 35 | 84 | 10.5 | 85 | 139 | 17.4 |
| 40 | 93 | 11.5 | 90 | 144 | 18.0 |
| 45 | 99 | 12.4 | 95 | 148 | 18.5 |
| 50 | 105 | 13.1 | 100 | 152 | 19.0 |
| 55 | 111 | 13.8 | 105 | 156 | 19.5 |
| 60 | 116 | 14.5 | 110 | 160 | 20.0 |
| 65 | 121 | 15.1 | | | |

It appears from this table that a difference of height of 8 feet corresponds to a difference in rate of combustion of about 1 pound per square foot of grate surface, the ratio of the grate to the chimney section being as 8 to 1. The quantities given refer to the average condition of chimneys of steam-generators. Professor R. H. Thurston's approximate rule for determining the amount of coal which will be burned per square foot of grate per hour, with good proportions, is: Subtract one from twice the square root of the height. Thus, supposing the chimney to be 49 feet high, the amount of coal burned will be 13 lbs. To determine the height required to give a certain rate of combustion, the same authority gives the rule: Add one to the weight to be burned per square foot per hour; divide by two, and square the quotient. The result is the height of the chimney in feet.

*Dimensions of Chimneys.*—For the theoretical considerations governing the dimensions of chimneys, the reader is referred to Weisbach's "Mechanics of Engineering: Heat, Steam, and Steam-Engines" (New York, 1878). Among other conclusions there reached, it is found that the breadth decreases as the height increases; and that, inversely, if the height is diminished the width must be increased. Other things being the same, a chimney which gradually widens toward the top can discharge more smoke than one which gradually diminishes. In order to withstand the force of the wind, the mean outer breadth of a square chimney should be one-eighth the height; if of circular section, the mean diameter should be one-twelfth the height.

In constructing chimneys having an internal section similar to that represented in Fig. 770, care should be taken not to contract the channel at the edges to a less area than that of the outlet at the top.

The famous chimney at St. Rollox, near Glasgow, of the height of 455½ feet, has the following dimensions:

*Dimensions of the St. Rollox Chimney.*

| DIVISION OF THE CHIMNEY. | Height above Ground. | Outer Diameter. | Thickness of Wall. | |
|---|---|---|---|---|
| | Feet. | Feet. | Feet. | Inches. |
| V. | 435½<br>350½ | 13½<br>10¾ | 1 | 2 |
| IV. | 210½ | 24 | 1 | 6 |
| III. | 114½ | 30½ | 1 | 10½ |
| II. | 54½ | 35 | 2 | 3 |
| I. | 0 | 40 | 2 | 7½ |

The foundation of this chimney has a depth of 20 feet and a diameter of 50 feet.

The following table exhibits the dimensions of many of the largest existing chimneys in Europe:

TABLE II., *showing Dimensions of various High Chimneys.* (*br = length of brick.*)

| NUMBER. | Height including Foundation, *h*. | Height excluding Foundation. | EXTERIOR DIAMETER. | | THICKNESS OF MASONRY. | | Decrease of Diameter on every 10 Feet of Height. | Relation of the Height to the Diameter of Base, $\frac{h}{d}$ | LOCALITY. |
|---|---|---|---|---|---|---|---|---|---|
| | | | Below *d*. | Above. | Below. | Above. | | | |
| | Feet. | Feet. | Feet. | Feet. | | | Inches. | | |
| 1 | 468 | 454 | 32 | $12\frac{3}{4}$ | 7 br. | $1\frac{1}{2}$ br. | 4.08 | 14.62 | Port Dundas, near Glasgow (Scotland). |
| 2 | 345 | 331 | 18 | $11\frac{1}{6}$ | 5 ft. | $1\frac{1}{2}$ ft. | 2.47 | 18.39 | Chemical factory, Barmen (Prussia). |
| 3 | 347 | 330 | 29 | $11\frac{1}{2}$ | $6\frac{1}{2}$ ft. | $1\frac{1}{2}$ ft. | 6.36 | 11.38 | Cast-steel works, Bochum (Prussia). |
| 4 | ... | 274 | $18\frac{1}{2}$ | $10\frac{3}{4}$ | 4 ft. | $1\frac{1}{4}$ ft. | 3.4 | 14.82 | Dye works, Hagen (Prussia). |
| 5 | 225 | 221 | $17\frac{5}{8}$ | $7\frac{5}{8}$ | $3\frac{1}{2}$ br. | 7 in. | 5.53 | 12.42 | Pontasser's chemical works (England). |
| 6 | ... | 175 | $20\frac{3}{4}$ | $7\frac{1}{2}$ | $4\frac{5}{6}$ br. | $8\frac{3}{4}$ in. | 9.07 | 8.44 | Alois iron works (France). |
| 7 | 173 | 155 | 17 | $6\frac{3}{4}$ | 3 br. | 1 br. | 7.91 | 9.14 | Hepburn's tannery, on the Tyne (England). |
| 8 | 167 | 161 | $13\frac{1}{2}$ | $5\frac{1}{8}$ | $3\frac{3}{4}$ ft. | 10 in. | 6.08 | 11.93 | Dye works, Barmen (Prussia). |
| 9 | 162 | 150 | $16\frac{2}{3}$ | $6\frac{2}{3}$ | $4\frac{1}{8}$ br. | 10 in. | 8.0 | 9.0 | "Einer Graben" chemical works, Barmen. |
| 10 | 141 | 132 | $11\frac{1}{2}$ | 5 | $2\frac{1}{2}$ ft. | 10 in. | 5.90 | 11.5 | Eisengarn factory, Barmen. |
| 11 | 133 | 126 | $9\frac{1}{5}$ | $4\frac{1}{8}$ | $2\frac{1}{2}$ ft. | 10 in. | 4.54 | 13.86 | Dye works, Oehde, near Barmen. |
| 12 | ... | 128 | $10\frac{1}{3}$ | $4\frac{1}{2}$ | $3\frac{1}{2}$ br. | 1 br. | 5.45 | 12.43 | St. Ouen, near Paris (France). |
| 13 | 131 | 126 | $15\frac{1}{2}$ | $6\frac{3}{4}$ | 4 br. | 1 br. | 8.31 | 8.14 | White's factory (England). |
| 14 | 136 | 124 | $11\frac{1}{2}$ | $6\frac{1}{3}$ | 3 ft. | 10 in. | 4.82 | 10.81 | Rolling mill, Hagen (Prussia). |

The Port Dundas chimney, marked No. 1 above, is the tallest in the world. It will be seen that the portion below ground, which contains not only the foundation proper but also the flues, with their arches and coverings, occupies a depth of 14 feet. The flues are four in number, placed at right angles to each other, so as to form an equilateral cross in the plan; they are of rectangular section, about 7 feet wide and 9 feet high each, and arched both at top and bottom. The foundation below these flues is built up from hard bricks, all placed on edge throughout several superposed layers up to the sides of the flues, which are arched and lined with fire-brick. The masonry above the flues is built with the bricks laid flat in the usual way. The internal diameter at the base is 20 feet, and it gradually contracts toward the top to 10 feet 4 inches diameter. The outline of the whole structure is of extreme simplicity, viz., the form of a truncated cone, without any deviation.

*Effect of Long and Short Flues.—*

TABLE III., *showing the Power of Chimneys to Steam-Boilers having Flues* 100 *feet long in circuit from Furnace to Base of Chimney.* (*From Box on Heat.*)

| SIZE AT TOP INSIDE. | 40 FEET. | | 60 FEET. | | 80 FEET. | | 100 FEET. | | 120 FEET. | | 150 FEET. | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Round. | Square. | Round. | Square. | Round. | Square. | Round. | Square. | Round. | Square. | Round. | Square. |
| Ft. In. | H. P. | H. P. | H. P. | H. P. | H. P. | H. P. | H. P. | H. P. | H. P. | H. P. | H. P. | H. P. |
| 1 0 | 6.4 | 8.1 | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... |
| 1 3 | 10.9 | 13.9 | 12.8 | 16.3 | .... | .... | .... | .... | .... | .... | .... | .... |
| 1 6 | 16.6 | 21.0 | 19.5 | 24.8 | 21.7 | 27.5 | .... | .... | .... | .... | .... | .... |
| 1 9 | 23.6 | 30.0 | 27.9 | 34.2 | 31.1 | 40.0 | .... | .... | .... | .... | .... | .... |
| 2 0 | 31.9 | 41.0 | 37.3 | 47.5 | 42.3 | 53.8 | 45.7 | 58.2 | .... | .... | .... | .... |
| 2 3 | .... | .... | 49.4 | 62.8 | 55.3 | 70.4 | 60.0 | 76.4 | 63.8 | 81.2 | .... | .... |
| 2 6 | .... | .... | 65.3 | 83.1 | 70.4 | 90 | 76.5 | 97.4 | 81 | 103 | 85 | 108 |
| 2 9 | .... | .... | 78 | 100 | 88 | 112 | 94.9 | 121 | 101 | 128 | 106 | 135 |
| 3 0 | .... | .... | 94 | 123 | 106 | 135 | 114 | 145 | 123 | 157 | 130 | 165 |
| 3 6 | .... | .... | .... | ..... | 150 | 191 | 163 | 207 | 175 | 223 | 186 | 237 |
| 4 0 | .... | .... | .... | ..... | 202 | 257 | 220 | 280 | 235 | 300 | 252 | 321 |
| 5 0 | .... | .... | .... | ..... | ..... | ..... | 360 | 458 | 388 | 494 | 415 | 528 |
| 6 0 | .... | .... | .... | ..... | ..... | ..... | ..... | ..... | 577 | 734 | 615 | 783 |

The power of chimneys in this table is three-fourths of their absolute maximum power; thus the maximum power of a chimney 3 feet 6 inches in diameter, 80 feet high, is $\frac{150 \times 4}{3} = 200$ horse-power.

The effect of different lengths of flue is shown in table IV., in which we have taken as an example a chimney 60 feet high and 2 feet 9 inches square, which by table III., with an ordinary flue 100 feet long, is equal to 100 horse-power. It will be seen that with a flue of one-half the length, or 50 feet, the power is increased to 107.6 horse-power only; and that with a flue 1,000 feet long, the power is reduced to one-half nearly. This may be applied to other cases. Say we require a chimney of 150 horse-power with a flue 1,000 feet long (from furnace to chimney); this would be equal to $150 \div .514 = 300$ horse-power in table III., and may be 120 feet high and 4 feet square. Again, a chimney of 50 horse-power, with a flue 400 feet long, must be equal to $50 \div .708 = 70$ horse-power in table III., and may be 80 feet high and either 2 feet 6 inches round or 2 feet 3 inches square.

TABLE IV., *showing Power of a Chimney* 60 *feet high,* 2 *feet* 9 *inches square, with Flues of different Lengths.* (*From Box on Heat.*)

| Length of Flue in Feet. | Horse-Power. | Length of Flue in Feet. | Horse-Power. |
|---|---|---|---|
| 50 | 107.6 | 800 | 56.1 |
| 100 | 100.0 | 1,000 | 51.4 |
| 200 | 85.3 | 1,500 | 43.3 |
| 400 | 70.8 | 2,000 | 38.2 |
| 600 | 62.5 | 3,000 | 31.7 |

*Effect of Internal Temperature in Chimneys.*—The discharging power of a chimney increases with increase of internal temperature, but not to an unlimited extent; for while the draught-power increases, so does the volume of air due to a given weight increase by expansion, and the result is that the *weight* of air discharged attains a maximum at a certain temperature, and an increase beyond that point results in a diminution of effect. This temperature is 525° according to Péclet; but this is true only for cases, such as reverberatory furnaces, where the fire escapes direct into the chimney, and, the flue being very short, friction may be neglected, and the whole power of the chimney is expended in generating velocity. Table V. shows in column 6 that the velocity and therefore the weight of cold air is then a maximum at 582−62=522° above the external air. But the weight of air necessary to carry off the heat increases rapidly as the temperature is reduced, as shown by column 8; and as a result the power of the chimney, as measured by the consumption of fuel, increases with the temperature throughout column 9.

TABLE V., *showing the Power with different Internal Temperatures of a Chimney 32 feet high with a very short Flue, as in Reverberatory and other Furnaces: External Air, 62°. (From Box on Heat.)*

| Volume of Air in the Chimney, External Air = 1. | Temperature of Air in Chimney. | Draught in Inches of Water. | | | Velocity of Air in Feet per Second. | | Pounds of Air per Lb. of Coal. | Pounds of Coal per Sq. Foot of Chimney per Hour. |
|---|---|---|---|---|---|---|---|---|
| | | For Velocity of Cold Air Entry. | For Extra Velocity of Hot Air on Exit. | Total. | Cold Air at Entry. | Hot Air at Exit. | | |
| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
| | ° | | | | | | | |
| 1.25 | 192 | .0891 | .0045 | .0936 | 19.73 | 24.69 | 400 | 14 |
| 1.5 | 322 | .1328 | .0222 | .155 | 24.10 | 36.15 | 200 | 33 |
| 1.75 | 452 | .1514 | .0486 | .200 | 25.72 | 45.00 | 133 | 53 |
| 2.00 | 582 | .1570 | .0790 | .236 | 26.30 | 52.60 | 100 | 72 |
| 2.25 | 712 | .1530 | .1070 | .260 | 25.99 | 58.44 | 80 | 89 |
| 3.0 | 1,102 | .1337 | .1783 | .312 | 24.18 | 72.50 | 50 | 133 |
| 4.0 | 1,622 | .1080 | .2430 | .351 | 21.70 | 86.90 | 33 | 178 |
| 5.0 | 2,142 | .0890 | .2850 | .374 | 19.75 | 98.75 | 25 | 217 |

With chimneys to steam-boilers the friction of the long flues must be considered as well as the head due to velocity, the result being that the maximum effect is attained when the volume of the internal air is between three and four times that of the external air, as shown by column 5 of table VI. If we admit $3\frac{1}{2}$ as the relative volume, the temperature would be about 1,300°; but with such a high temperature there would be an enormous loss of useful effect, and the power of the chimney would be only 116÷107=1.085, or 8.5 per cent. greater than with double volume, which experience has shown to be the best in practice. The table shows, however, that a variation of 130° either way has little influence on the power of the chimney; thus, with volume $1\frac{3}{4}$, we have 100÷107=.9346, or .0654=6.54 per cent. less, and with volume $2\frac{1}{4}$, 112÷107=1.047, or 4.7 per cent. greater power than with volume 2. Column 5 of table VI. gives the ratio of power of the chimney at the different internal temperatures, and column 6 the *maximum* consumption of fuel per square foot.

TABLE VI., *showing the Power with different Internal Temperatures of a Chimney 80 feet high, 2 feet 9 inches diameter, with a Flue of the same Area 100 feet long, from Furnace to Foot of Chimney. (From Box on Heat.)*

| Volume of Air in the Chimney, External Air = 1. | Temperature of | | Draught of Chimney in Inches of Water. | Ratio of the Power at different Temperatures. | Pounds of Coal per Square Foot of Chimney per Hour. |
|---|---|---|---|---|---|
| | Air in the Chimney and Flue. | External Air. | | | |
| 1 | 2 | 3 | 4 | 5 | 6 |
| | ° | ° | | | |
| 1.25 | 192 | 62 | .234 | 71 | 120 |
| 1.5 | 322 | 62 | .390 | 89 | 150 |
| 1.75 | 452 | 62 | .500 | 100 | 168 |
| 2.00 | 582 | 62 | .585 | 107 | 180 |
| 2.25 | 712 | 62 | .650 | 112 | 188 |
| 3.0 | 1.102 | 62 | .780 | 116 | 195 |
| 4.0 | 1.622 | 62 | .890 | 116 | 195 |
| 5.0 | 2,142 | 62 | .926 | 114 | 192 |

*Straightening Tall Chimneys.*—It is a well-known fact that high chimneys, however carefully built, often lose their original straightness soon after their erection and assume an inclined position or a curved shape, so that it becomes necessary to straighten them.

The Port Dundas chimney (No. 1 in table II.) underwent during its erection one of the most interesting and curious operations known in masonry practice, viz., the straightening by sawing the mortar-joints. This operation has since been frequently resorted to in similar cases, and has always proved very successful. The mortar in the newly-built portion of the work being still soft and plastic, the pressure of the wind caused a lateral deflection of the column, amounting to 7 feet 9 inches from the vertical at the top. The whole structure was thereby endangered, and in order to restore its stability it was necessary to bring it back to the vertical line. The operation of sawing, which was then resorted to, consists in attacking the mortar-joints at the windward side, and reducing

their thickness so as to compensate for the compression of the mortar-joints at the opposite side effected by the pressure of the wind. The sawing was done by first removing a portion of the brickwork inside the chimney, forming a groove about 14 inches wide half around the interior surface of the chimney. Narrow holes were then cut out by means of chisels, the workmen standing upon the internal scaffolding, and working exclusively from the inside. A saw with a single handle—in reality an old carpenter's saw—was the instrument employed. It was passed through one of the holes cut out, so as to work through a horizontal mortar-joint, and it was then worked by hand, removing the mortar, as it proceeded through the joint, through part of the half circle on the windward side. Generally two saws were simultaneously employed, working in opposite directions toward each other. The mortar-joint operated upon was kept wet by a jet of water during the whole process, and the removed brickwork in the interior was replaced by fresh bricks as the sawing proceeded. As soon as the greater portion of any one mortar-joint is sawn through, the effect produced upon the superincumbent mass causes the latter to settle, and a considerable pressure is thereby exerted upon the saw, making it difficult to withdraw. If the precaution is taken to commence sawing at the lowest joints, and proceed in succession to the higher cuts, this difficulty is considerably lessened. In the case of the Port Dundas chimney, sawing was commenced at the top, 128 feet below the chimney cope, and 12 cuts were made at unequal distances, varying from 12 feet to 49 feet. Mr. Townsend, who conducted this operation personally, judging by the effects produced by each incision, selected the spot for the next cut, proceeding gradually downward until the last cut, 41 feet from the ground, restored the whole chimney to a perfectly perpendicular position.

In the spring of 1868 the chimney at Barmen marked No. 2 in table II. suddenly assumed an inclined position toward the northeast. The deflection of the chimney was considerable at the end of May, and seemed yet to increase, and threatened an overthrow. Some layers of bricks in the chimney at distances of 50 feet from each other were painted black outside. The height of these black lines above the socle being known, these lines were, by means of a theodolite, projected on a plank situated on the socle of the chimney, to find the deviation from the vertical line at these different heights. It was thus ascertained that the chimney at a height of 251 feet was out of line 45 inches; at 210 feet, 30 inches; at 160 feet, 16 inches; at 110 feet, 5 inches. The socle stood perpendicular. As the deviation was still increasing, and as it would have done too serious an injury to the manufactures of the establishment to set the chimney temporarily out of use, it was necessary that action should be taken in the matter. The ordinary method of straightening chimneys was resorted to. A hole was made through the whole thickness of the masonry on that side of the chimney which required lowering, 4 feet above the top of the socle. Into this hole a saw was introduced, with which a horizonal cut through one half the chimney was attempted. But as the thickness of the wall was considerable and the bricks were hard, and as the saw could be manipulated from one of its extremities only, the effect of sawing after two hours' work was scarcely perceptible. The hole through the chimney having been made without trouble, and the difficulty experienced in sawing, led to the idea to gradually remove a whole layer of bricks, replacing it by a thinner layer, thus to produce the desired slit. Before, however, this operation was performed, the experiment was made with an old inclined chimney 120 feet high. When the method had there proved practicable and successful, it was concluded to treat the new chimney the same way. A layer of bricks was broken out by means of pointed cast-steel bars from 1½ to 5 feet in length, and flat shovels with long handles were used to lay those bricks which had to be placed near the inside of the chimney. A space of 5 inches was left each time between the newly-laid bricks and the old ones of the next division, to break out the latter with greater facility. As soon as the operation was performed, the chimney began to move, and by slight oscillations settled down on the new layer of bricks, and there remained quiet.

*Defects of Chimneys.*—Smoky chimneys have a variety of causes, such as imperfections in the flue, too contracted dimensions, too rough an inner surface, openings which admit cold air and chill it, and (the most common of all) too large an opening at the fireplace or throat. Count Rumford paid much attention to the cure of smoking chimneys. He generally found the cause to be too large a throat, and his usual remedy was to diminish it by building a bench of brick in the back of the fireplace, reaching up to the throat, and to lower the fireplace somewhat. Sometimes the aperture at the top is too large, particularly if it is below the level of some neighboring house, hill, or high trees, from which the wind may be reflected down into the chimney, or over which it may fall, and thus beat down the smoke. An inadequate admission of air into the room in which is the fireplace will cause a chimney to smoke, a circulating current being thus as effectually prevented as if the flue itself were in great part obstructed. The opening of a door or window often shows the cause of this trouble by at once removing it. When two chimney-flues come down into one room, or into two rooms which connect by an open passage, the burning of a fire in one flue may establish an upward current, which is supplied with air drawn down the other. Any attempts to make the second chimney draw could only succeed by closing the connection between them, or supplying the first with the air it requires from some other source. When a chimney smokes in consequence of the wind beating down, the height may be increased, or the diameter at the top contracted; but the most efficient remedy is usually found by adjusting a bent tube to the top of the chimney, and keeping its mouth turned in the direction of the current of air by means of a vane. The effect of the latter change is to admit a smaller quantity of air, and this is dispersed through the large body in the flue without being felt at the base. The worst chimneys usually draw well when a stove is substituted for the fireplace, and the pipe is led into the chimney. This causes an increased current in the smaller channel, being equivalent to contracting the throat of the chimney when the fireplace is used.

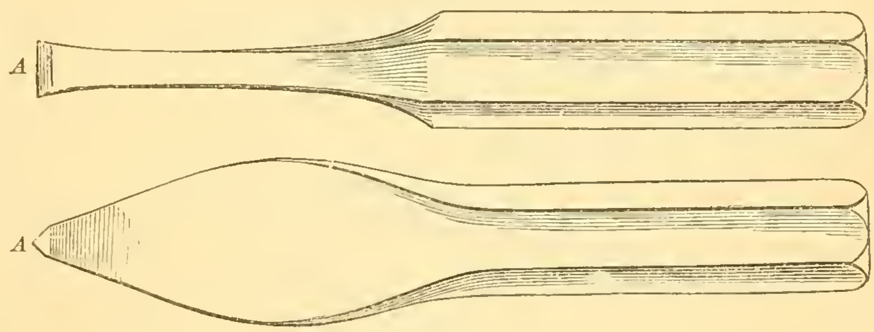
*References.*—For practical details relative to the construction of an iron chimney 279 feet high at Creusot, France, see *Engineering*, xiii., 364. A description of the manner of taking down a large chimney is given in *Engineering*, xii., 188. With reference to stability of dwelling-house chimneys,

see *Engineer*, xl., 220; for concrete chimneys, *Scientific American*, xxix., 39. See also "A Treatise on Heat," Box, 2d ed., London, 1876; "Factory Chimneys and Boilers," Wilson, London, 1877. Also articles DAMPER and BOILERS.

CHISEL. A wedge-shaped cutting tool more especially designed for paring and splitting. The forms of chisel vary according to the work which they are intended to perform and the material to be operated upon. In all cases the tool may be regarded as a wedge formed by the meeting of two straight or of two curvilinear surfaces, or of one of each kind, at angles varying from about 20° to 120°. Occasionally, as in the chipping chisel and the turner's chisel for soft wood, the tool is ground from both sides, or with two bevels or chamfers; at other times, as in the carpenter's chisels and plane-irons, the tool is ground from one side only, and in such cases the general surface or shaft of the tool constitutes the second plane of the wedge: this difference does not affect the principle. The general principles underlying the construction of cutting tools will be found under PLANES. Stone-workers' chisels are described under STONE-WORKING TOOLS. For the uses of the chisels for turning, see LATHE-TURNING TOOLS; for carving, see CARVING TOOLS.

*Chisels for Metal.*—Chipping chisels are employed for dressing metal surfaces. Fig. 772 represents a cross-cut or cape chisel of this type, which is usually made of hexagon steel, the cutting end *A* being tempered to a blue color. The use of the cape chisel is to cut grooves. In chipping large surfaces, these grooves are made closer together than the width of the flat chisel, and are intended to assist the operation of the latter by preventing its corners from digging in, as they are otherwise apt to do. The flat chisel shown in Fig. 773 is then employed to cut off the ridges of metal remaining between the grooves. The cutting edges of these chisels should be firmly held against the work. For hollow curved surfaces a round-nosed chisel is used, the end being ground after the manner of a gouge, and the angles forming the cutting edge being more obtuse. In Fig. 774 the dotted line shows the form of a side chisel used for cutting out square corners. Fig. 775 represents a diamond-point chisel employed for cutting out the sides of keyways, mortises, and other inside work.

772.



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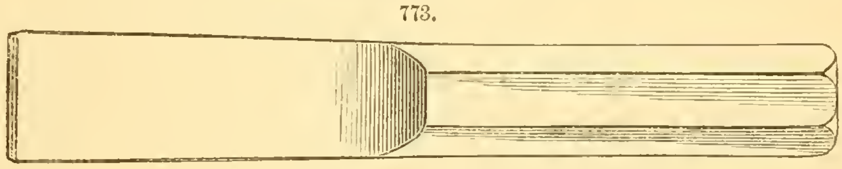

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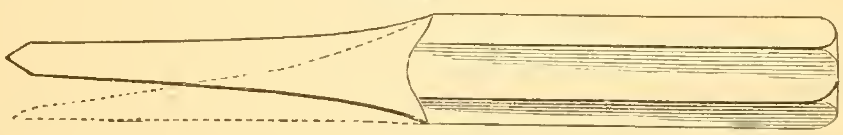

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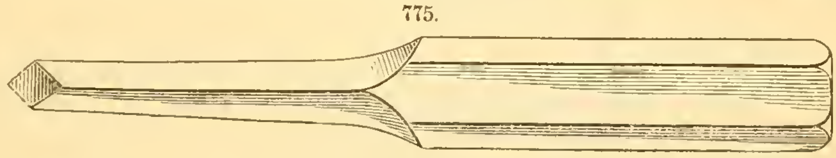
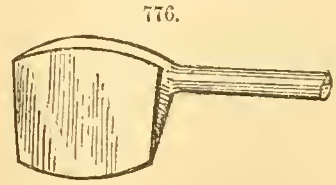


In a rod chisel for cutting hot metal, the angle of the long taper portion should be 10° or 12°, and the angle of the short beveled part for cutting about 40° or 50°. Chisels for cold iron require the long taper part to be about 30°, and the short bevel for cutting about 80°. All rod chisels are best when made entirely of a tough hard steel, without any iron being added to make the head. Such a chisel will sustain a severe hammering without much injury to the head and cutting part, if only about half an inch is hardened and the head made as soft as possible. After the cutting end has become too thick with hammering during ordinary use, or has become otherwise damaged, the lower part of the taper portion is thinned to a proper shape, and only a short length of the chisel hardened as at the first making. Every time a chisel is repaired by such thinning, it is advisable to cut off about a quarter of an inch of the thin ragged end, because this portion becomes burnt during heating, and also contains several cracks that are not visible to an unassisted eye. In chisels for steam-hammers the angles of the taper parts are about the same as those of small chisels; but the cutting parts are thicker and of greater length.

776.



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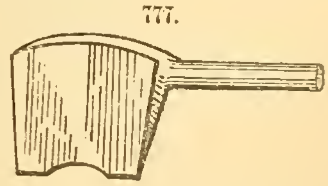
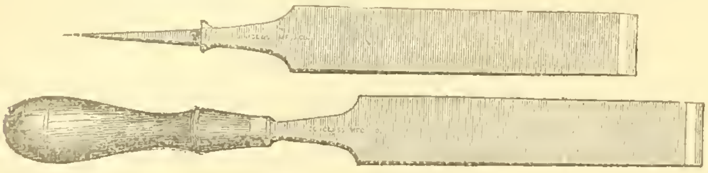


A very useful class of chisel is that named *trimmer*, represented in Fig. 776. This is used for cutting all sorts of thin bars, rods, and plates; also for removing all superfluous metal that may be attached to any forging which is being shaped to the finished dimensions. To permit the free use of a trimming chisel, its cutting edge is convex, because this form enables the smith to slide the

tool easily along a cut which may be of great length, although not very deep. In arched chisels the cutting edge is concave, as shown in Fig. 777. These chisels are useful for making a square cut through an axle or shaft, while it is being rotated on a gap-bearing block, which maintains the shaft in proper position for cutting. Concave chisels are sometimes made with two handles welded to short arms extending from the tool. The implement may then be supported beneath the hammer by two men, one at each handle. To avoid the necessity of holding a chisel on the work, it may be keyed to the hammer; and if a bottom chisel is also to be used, this is keyed to the anvil-block.

778.



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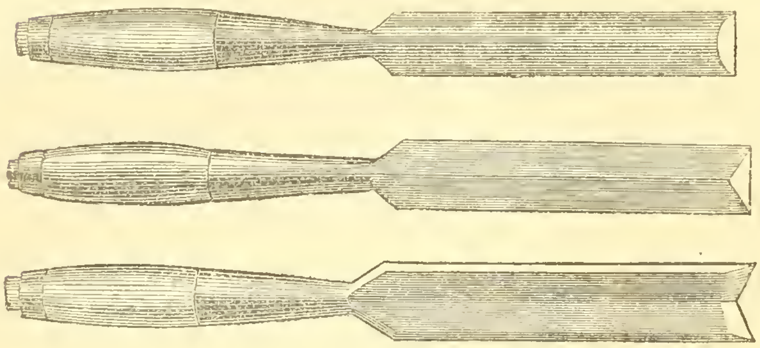

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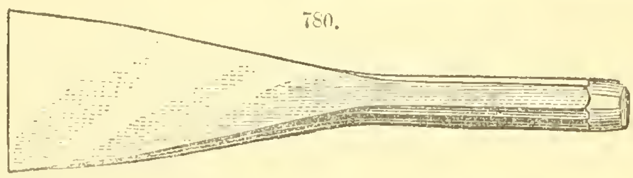

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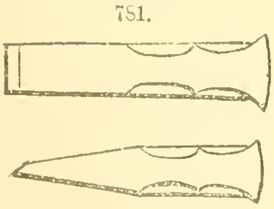

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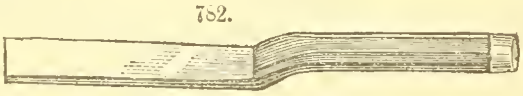


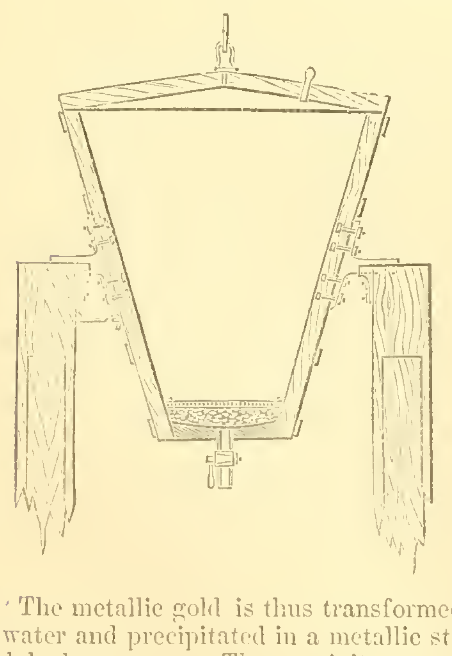
783.

The forging, manufacture, and detailed uses of metal-working chisels are fully discussed in the "Mechanician and Constructor for Engineers," by Cameron Knight, New York, 1869.

*Wood Chisels.*—The construction of these tools is described under PLANES. There are two types, depending upon form: the firmer-chisel and the framing chisel. The *firmer* is made with a tang, which is inserted in a wooden handle as shown in Fig. 778. The *framing* chisel, used for heavier work than the firmer, has a socket in which the wooden handle is inserted. Three forms of framing chisel, the oval-back, bevel-back, and corner chisel, are represented in Fig. 779. In Fig. 780 is shown a chisel with a broad edge for plaster-cutting. Figs. 781 and 782 are calking chisels, and Fig. 783 is a driving chisel.

CHLORINATING MACHINERY. Chlorination is a process for the extraction of gold by exposure of the auriferous material to chlorine gas. The metallic gold is thus transformed into soluble chloride of gold, which can be dissolved in cold water and precipitated in a metallic state by sulphate of iron, or as sulphide of gold by sulphuretted hydrogen gas. The precipitate may then be filtered, dried, and melted with suitable fluxes, to obtain a regulus of malleable gold. The powdered and roasted ore is placed in leaching vats, Fig.

784.



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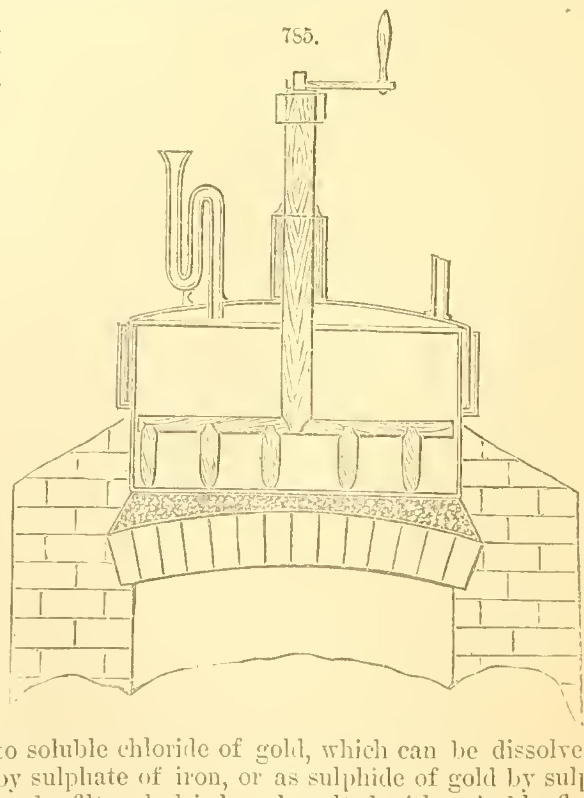


784, which are simply wooden vats swung on gudgeons, and with a filter on the bottom made of pieces of quartz laid under a perforated earthenware cover. Pipes in the covers connect the vats together, so that the gas which is introduced at the bottom passes through the whole row of vats. The ore is slightly dampened, but must not be wet.

786.

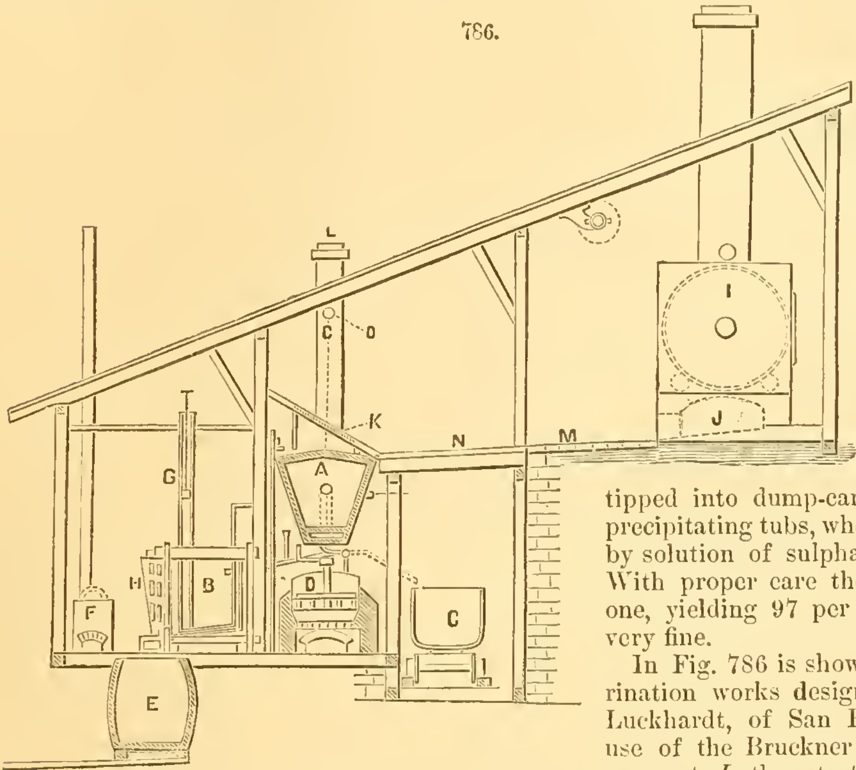


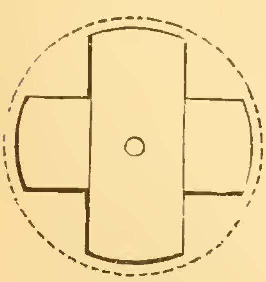

Fig. 785 shows the gas-generator. It consists merely of a lead chamber, containing an agitator of hard wood, and closed by a cover resting in a water-joint. The whole rests on a sand-bath. Between the generator and the leaching vats is placed a wash-bowl, where any hydrochloric acid in the gas is removed. When the operation is ended, the soluble chloride of gold is extracted by warm water, and the spent ore is tipped into dump-cars. The solution is run to precipitating tubs, where the gold is thrown down by solution of sulphate of iron, oxalic acid, etc. With proper care the process is a very perfect one, yielding 97 per cent. of the gold, which is very fine.

In Fig. 786 is shown an arrangement of chlorination works designed by Messrs. Riotte and Luckhardt, of San Francisco. It includes the use of the Bruckner roasting furnace, which is seen at *I*, the starting-point of the operation. The leaching vats are placed at *A*, in a row, with the gas-generator *D* in the centre. *C* is a rail-car for removing the spent ore from the building, while the precipitating tubs are seen at *B*. At *E* is seen the waste-tub, where the water runs through sawdust before being finally discharged.

CHUCKS. See Lathe and Drill Chucks.

CHURNS. The churn which is most in use in this country is the original "dash-churn," and it is claimed by butter-makers who have had large experience to be the best. The dash-churn is hard to operate by hand, which is one objection to its use on a small scale; but, as all churns are worked by machinery when many are employed, this objection is done away with. The best dash-churns are barrel-shaped, as represented in Figs. 790, 791, and 792, having a moderate bulge at the middle, and the dasher is large enough to occupy three-quarters of the area of the horizontal section of the

787.



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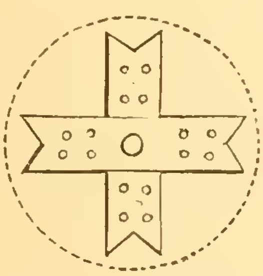

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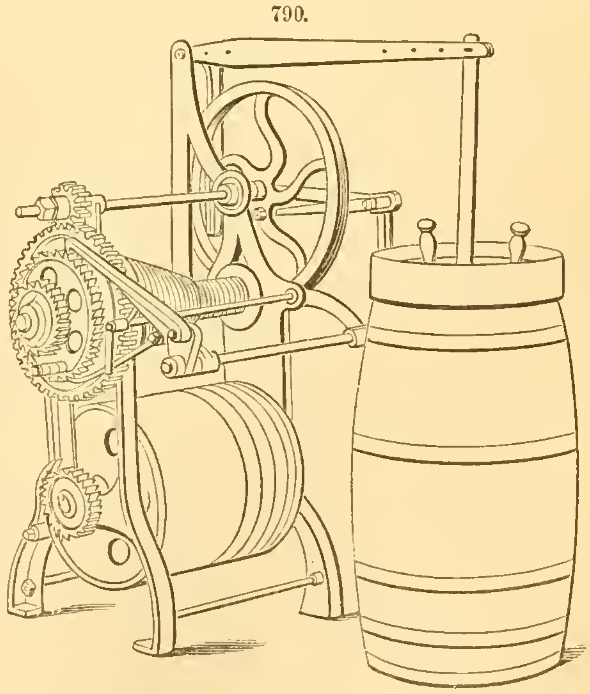

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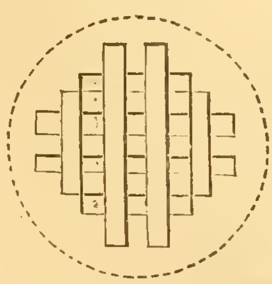

middle of the churn. The dasher should be a complete circle, or have the form of one of the dashers shown in Figs. 787, 788, 789. A very ingenious apparatus, called the Odell & Smey spring motor, is shown in Fig. 790, for operating churns. The motive force is imparted by a well-tempered volute spring of steel, inclosed in a barrel or drum hung in an iron frame, and connected by means of a

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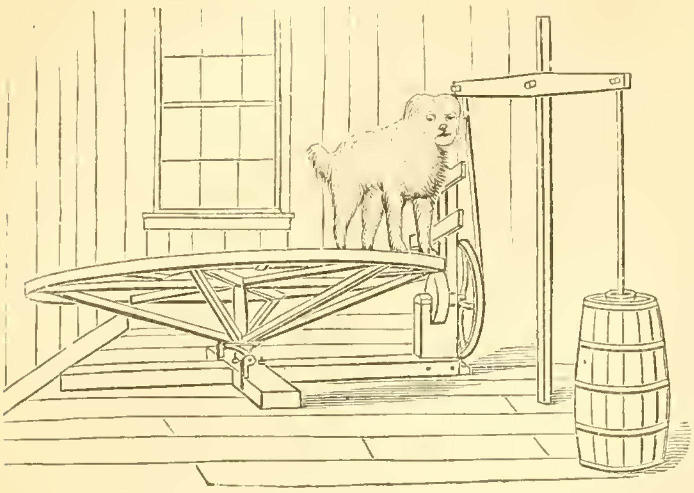
791.



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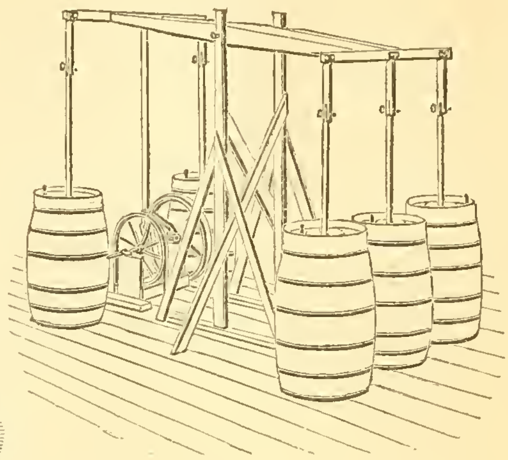
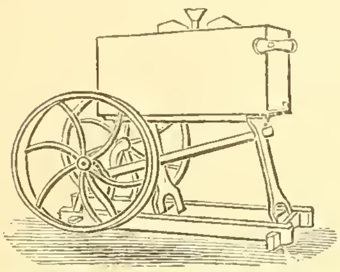


wire rope or cord with a fusee, whereby the waning strength of the spring, as it runs down, is counterbalanced and equalized. The motor runs for about half an hour with one winding up, and it requires about $1\frac{1}{2}$ minute to rewind it. In Fig. 791 is represented the Keystone animal power for churns, the arrangement of which is clear from the illustration. In Fig. 792 is represented the manner in which a number of churns are attached to the motive-power. Usually four churns are placed in pairs opposite, or two side by side, so as to be all worked by the power at the same time.

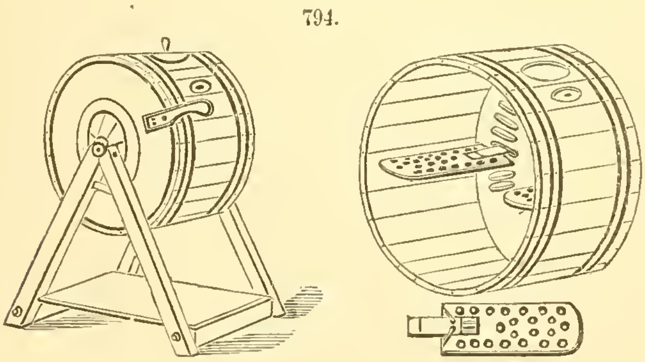
793.



Several churns have lately been introduced that operate on the same principle as the dash-churn, producing the butter by concussion. "Bullard's oscillating churn" is shown in Fig. 793. This churn is simply a box, without floats or paddles, adjustable to an oscillating table, to which are attached two balance-wheels; the motion is forward and backward, the balance-wheel overcoming the resistance of the cream and causing the churn to work easily. This churn is very simple in construction, and easily kept in repair.

In Fig. 794 is represented the "Howe churn." The principle of producing the butter in this

794.



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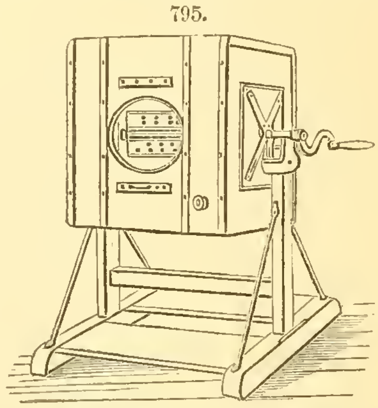
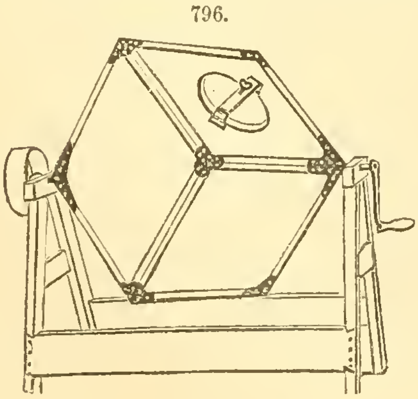


churn, when properly worked, is the same as in the dash-churn. The operator must cause the dash-boards to strike the cream with force similar to the blow of concussion in the dash-churn. The

796.



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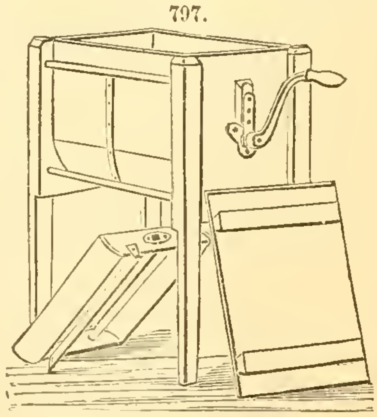
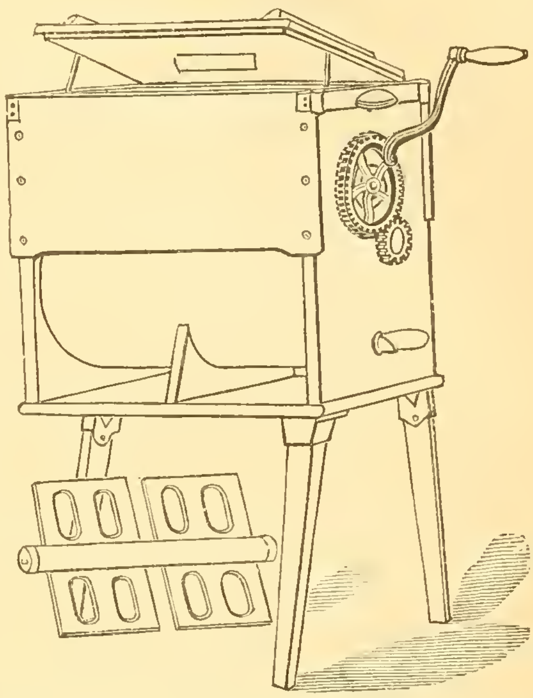


proper point for the return swing of the churn will be apparent by the churn moving back itself, which movement must be assisted by slightly jerking it at the beginning of its return swing, to

produce the blow of concussion. Each dash-board must make the blow on each swing. The desired motion or stroke is easily acquired with practice, and butter is quickly produced.

The "revolving box-churn" is shown in Fig. 795 The cover of the churn is easily adjusted, and admits of no waste of cream. It contains a revolving cream agitator, running in an opposite direction, thereby hastening the time of churning.

798.



"Whipple's rectangular churn," shown in Fig. 796, has neither dasher, floats, nor agitators of any kind, the cream only acting upon itself and the inner flat surface of the churn. Suspended from diagonal corners, as the churn revolves the cream constantly falls from corner to corner, thus giving a diversified action, and preventing the accumulation of what is called "dead" or half-churned cream.

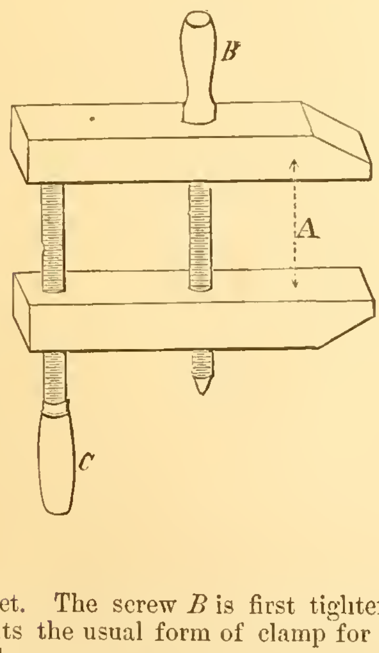
The Blanchard churn is represented in Fig. 797. Of this, and of the Union churn, Fig. 798, the construction is clear from the engravings. See Dairy Apparatus. H. A. M., Jr.

CHUTE. An inclined trough forming a feeder of materials to machines, or of water to a water-wheel. Also an inclined plane on which logs are passed down hill-sides.

CLAMMING MACHINE. A machine in which an engraved and hardened die is made to rotate in contact with a soft steel mill, in order to deliver a cameo impression thereupon. The mill is used to indent copper rollers for calico-printing. (See Engraving.)

CLAMP. A device for temporarily holding the parts of a piece of work firmly together. Fig. 799 represents the form of clamp used by joiners to hold glued joints while the glue is hardening. The work is placed between the jaws at $A$, and the screws are adjusted so that the jaws just touch

799.

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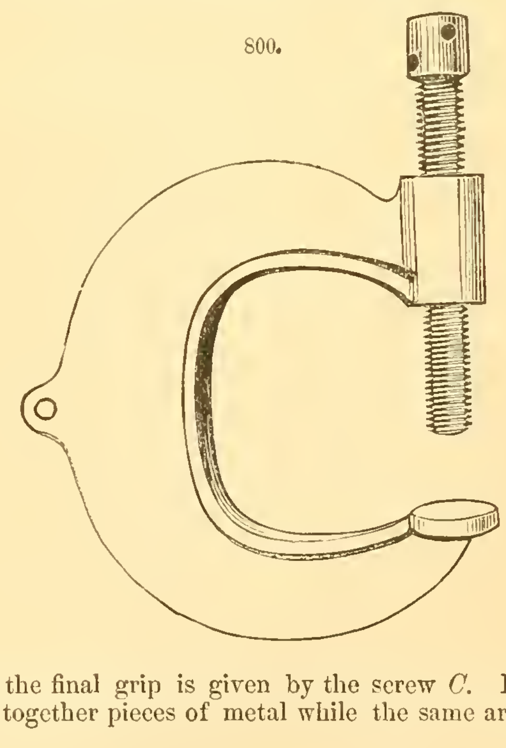


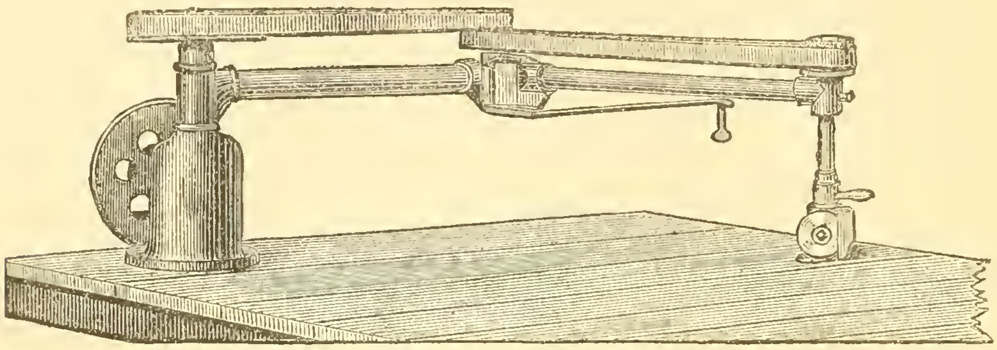
the object. The screw $B$ is first tightened, and the final grip is given by the screw $C$. Fig. 800 represents the usual form of clamp for holding together pieces of metal while the same are being operated upon. J. R.

CLOCKS. See Watches and Clocks.

CLOTH-CUTTING MACHINE. An apparatus for cutting cloth for tailors' purposes. The Penno machine, represented in Fig. 801, consists of a vertical shaft driven off a counter-shaft by a bevel-gear wheel. Attached to a hollow standard, in which this shaft runs, is a horizontal jointed arm, carrying at its outer extremity a small vertical shaft, which is driven by belts arranged as shown in the illustration; this vertical shaft drives by bevel-wheels a revolving cutter 4 inches in diameter, mounted on a small stand and furnished with a handle. The radius of the arms is 6 feet, and they are made of brass tubes, the outer length being supported by a spring from the joint; the cutter makes 2,000 revolutions per minute, and with it a skillful operator can cut from 20 to 80 layers of cloth, according to the quality of the material, and can follow any description of line, either curved or straight. The foot-plate under the cutter preserves the table from injury, and the cutter can be moved over the surface of the table within the radius of the arm with the greatest ease. A revolving emery-wheel fixed on one corner of the table enables the cutter to be sharpened without stopping

the machine. A clamp is used for holding several layers of cloth together when moving them from one table to another, by which the old-fashioned screw clamps are dispensed with. It consists of a small casting, the foot being flat and the stem of a triangular section; on the latter slides loosely another flat casting, having a triangular aperture to fit the stem. The elasticity of the cloth presses upward the outer end of the upper arm of the clamp, and by doing so increases the friction on the

801.



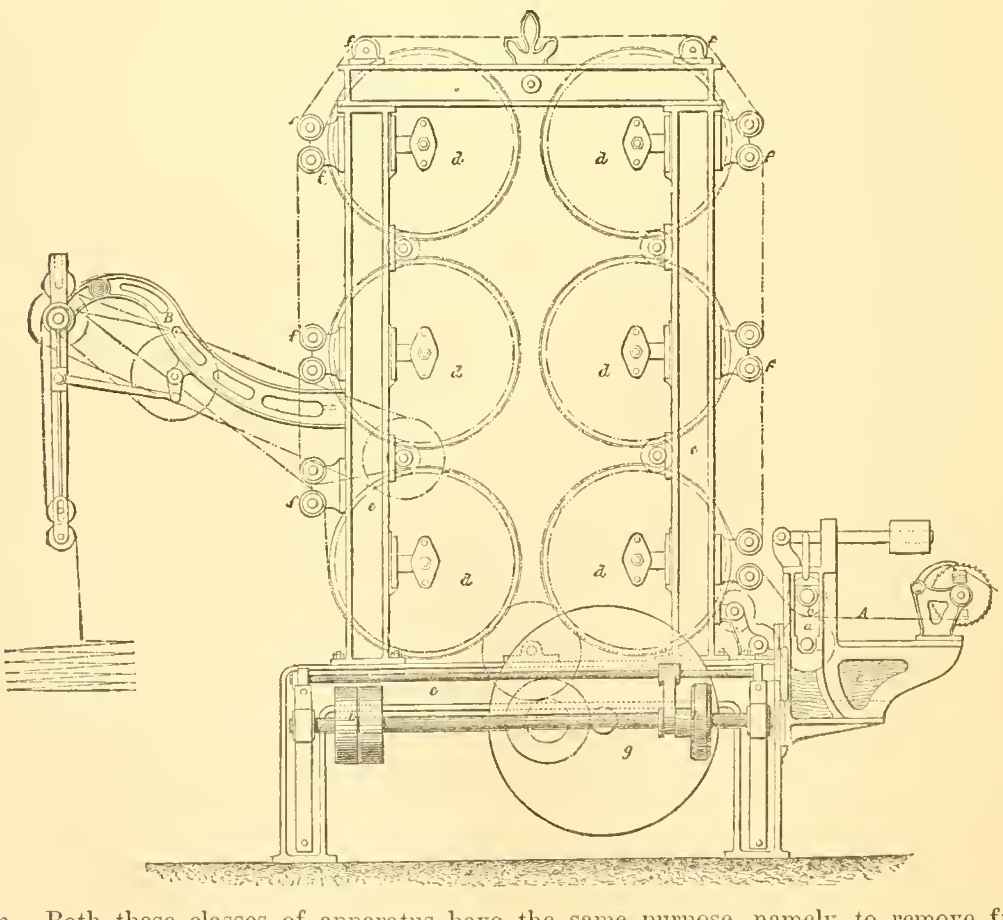
flat side of the stem to such an extent that the arm cannot move. To release the clamp, the upper arm has to be brought to a horizontal position, when it will slide up the stem.

Mr. Albin Warth also exhibited at the Centennial Exposition, 1876, two machines for cloth-cutting. The traveling machine has an arm running on a little railway, secured to the table, and carrying a revolving cutter driven by belting—the power being communicated from the counter-shaft by an endless band which surrounds the traveling pulley attached to the arm. The standard machine has a revolving cutter driven by machinery placed underneath the table; this cutter can revolve on its centre, but cannot travel over the table.

CLOTH-FINISHING MACHINES. (See also Calender, Calico Printing, and Fulling Machines.) Cloth-finishing machines prepare the surface of woven fabrics, so as to improve their appearance, and often in the case of inferior goods to cover the poor quality of the material. Nearly all stuffs when taken from the loom contain certain impurities and dressings, such as glue, which have been used to keep the warp together, and which are therefore of a sticky nature. To remove these substances, washing machines are used. (See Laundry Machines.)

*Drying Machines.*—These are contrivances for removing the water from the stuffs and for dry-

802.

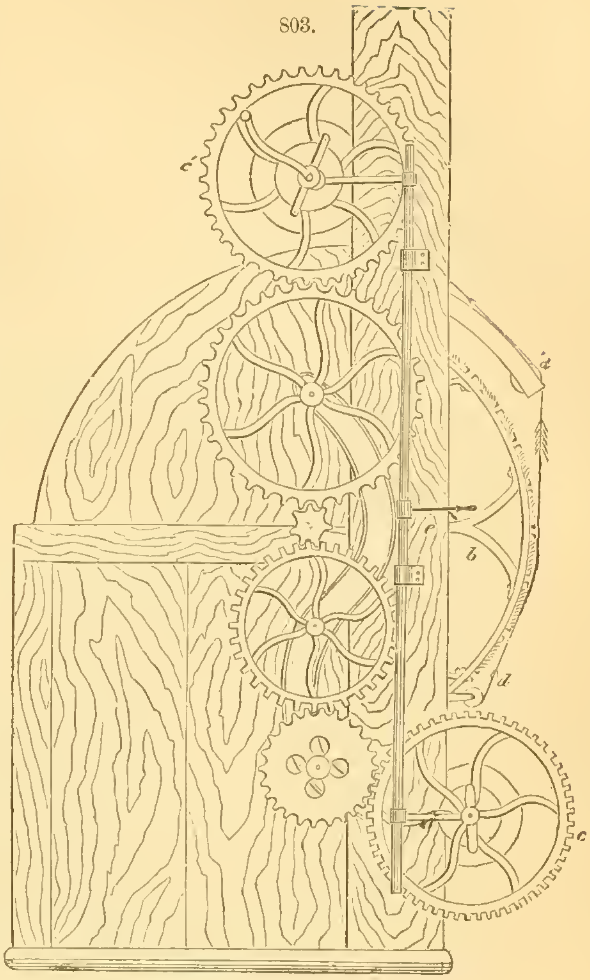


ing them. Both these classes of apparatus have the same purpose, namely, to remove from the stuff the moisture which it has absorbed during the processes of washing and fulling. This moisture is of two kinds, one part being held mechanically by the stuff, while the presence of the other part is due to the hygroscopic qualities of the material; this latter portion is known to be very predomi-

nant. The mechanically held moisture is now generally removed by means of centrifugal drying machines (see SUGAR-MAKING MACHINERY), while artificial heat is required to effect the remainder of the drying. Dr. Herman Grothe has published a work on this subject, in which he shows, by practical results obtained by the use of centrifugal machines, that the rotary drying of moist stuffs is only economical within certain limits, and that the construction of the centrifugal machines themselves is not yet perfected, as most of them have to drag with them vessels and contrivances which are much too heavy. A well-designed centrifugal machine should represent a correct combination of mass and strength, and should possess at the same time moving parts which offer little friction, and the necessarily rapid motion of which does not produce any loss of power, while the machine should also be provided with arrangements for stopping the rotary motion almost instantaneously.

The drying machines intended for removing the more closely combined portion of the moisture by means of heat are of various systems. One of improved construction (German) is represented in Fig. 802, and is more especially adapted for calico-drying. It is arranged on the vertical system, and is used for effecting the simultaneous drying and starching of woolen and half-woolen stuffs, which are starched on one side only. For this purpose the stuff passes at first through the starching apparatus $A$, consisting of the squeezers $a$ $b$ and the box $c$, which contains the finishing or covering matter through which the lower roller $a$ revolves; the stuff passing through the two rollers $a$ $b$, the finishing matter is very uniformly transferred to and impressed upon the surface, and the small irregularities formed in weaving are thus completely covered. From here the stuff passes into the drying apparatus proper, consisting of six copper cylinders $d$ $d$ heated by steam through the hollow frames $c$ $c$. These cylinders, which are constructed for a pressure of from two to three atmospheres, are provided with cast-iron bottoms, the latter being fixed in such a manner that they may easily be removed. The guide-rollers $f$ $f$ pass the stuff with the unstarched side on to the cylinders, so that the breaking up of the finishing matter, the clouding of the stuff, and the greasing of the cylinders are prevented, while the drying of the matter is well and uniformly accomplished. From the last cylinder the stuff

803.



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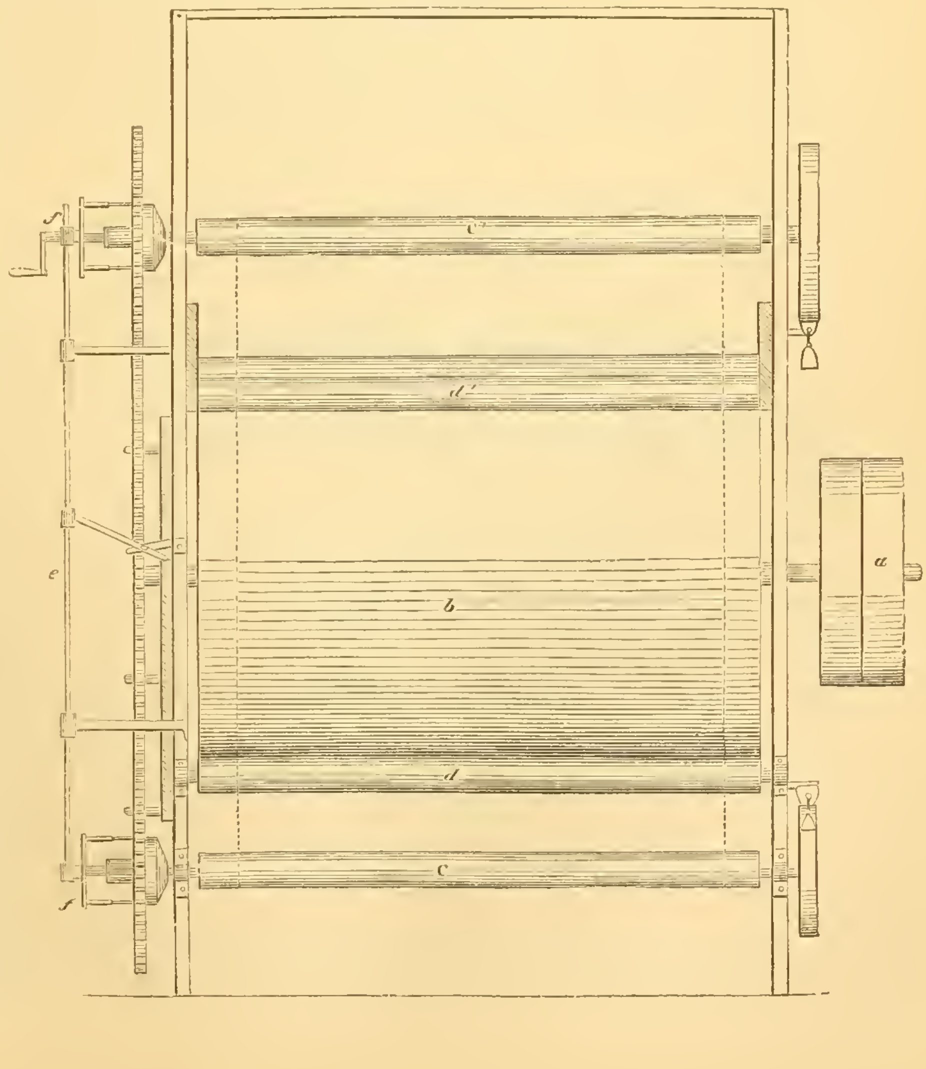
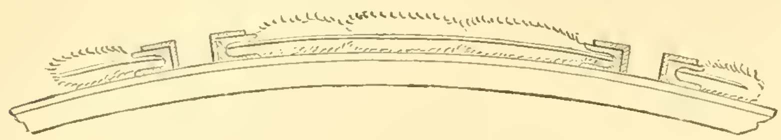


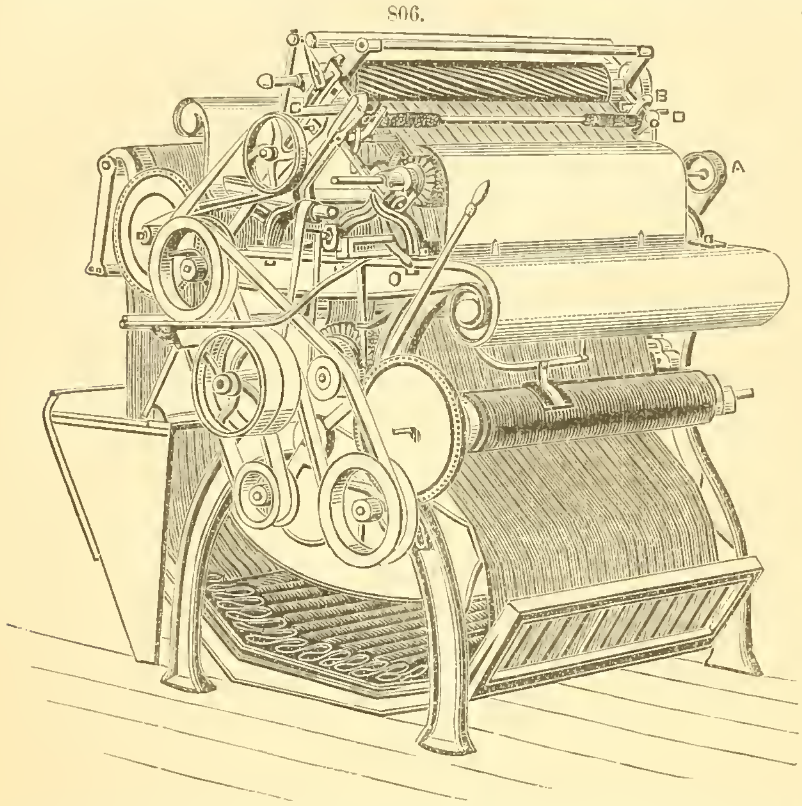
passes into the folding apparatus carried by the arm *B*. The water arising from the condensation of the steam is continually taken off from rollers and frame. The motion of the cylinder is produced by the friction-gear *g h* and the pulleys *i*; and according to the speed required for the cylinders, the friction-pulley *h* is moved along its axle either toward the centre or the circumference of the face-plate *g*.

805.



Cloth-like stuffs are placed in the fulling-mill in order to facilitate the closing or felting of the materials. (See FULLING MACHINES.) Woolen stuff is next taken to the gig-mill.

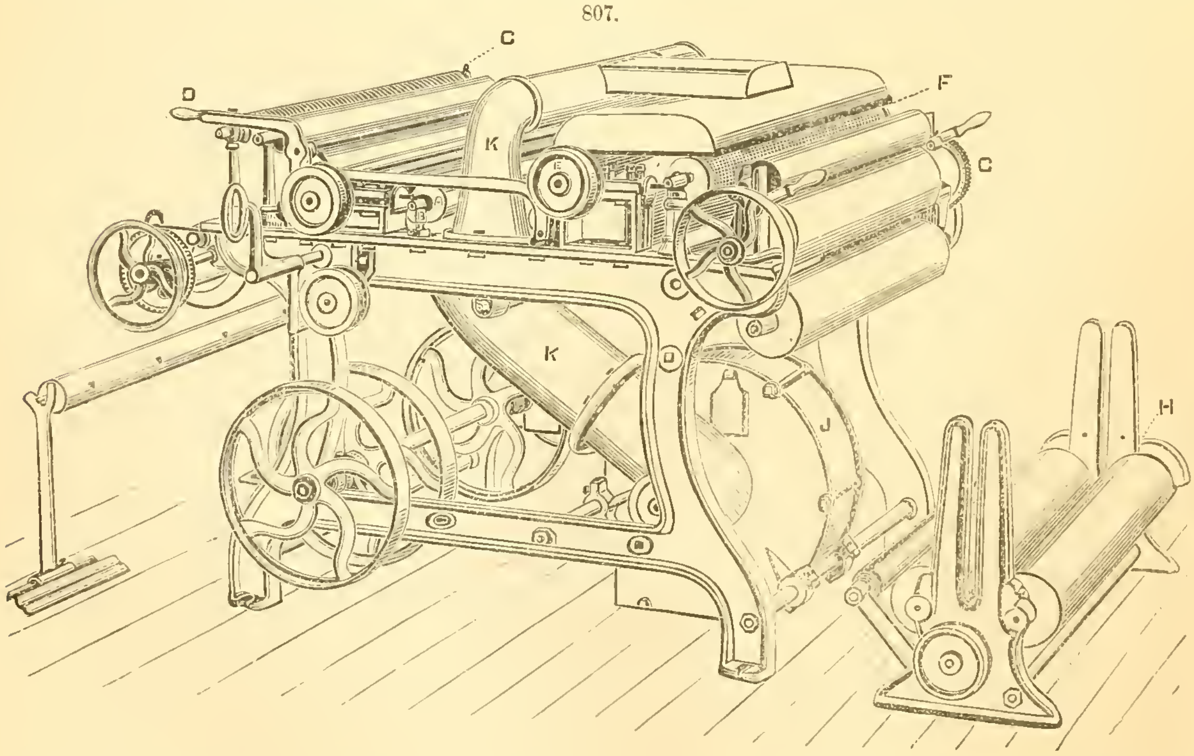
806.




*The Gig-Mill.*—An example of this machine, which is used for napping the fabric, is given in Figs. 803 and 804. The cloth to be napped is first wound on the roller *c'*, then passed down over the two straining rollers *d' d* to the cloth-roller *c*. By means of the shaft *e*, which is mounted at each end with two slipping clutches *f f*, *c'* is thrown out of gear, and the lower roller *c* thrown in. The cloth is then drawn downward over the revolving drum *b*, which is set with teasels, as seen in Fig. 805, until the whole length has passed over. The action of the two cloth-rollers is then reversed, *c'* being thrown into gear, and the cloth passes back again over the teasels; and this is continued until the nap is sufficiently raised. The straining roller *d'* may be adjusted to give more or less strain on the cloth at will.

From the gig, as described, cloth passes to the *Woolen-Cloth Shearing Machine*, Fig. 806. The example we illustrate was built by the Parks & Woolson Machine Company, Springfield, Vt. The rotary brush *A*, revolving in an opposite direction to that in which the cloth is moving, raises the nap which has been formed

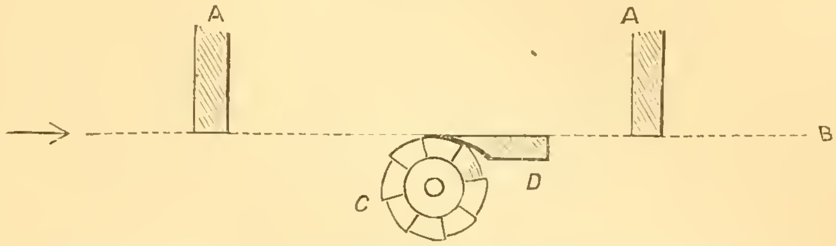
807.




by the action of the gig, so as to prepare it for the action of the helical blades of the shear *B*, which acts against a ledger-blade, not seen in the drawing. The cloth is brought up to the point

of contact of the shear-blades by the rest-bar *C*, the distance of which from the shears is adjusted by set-screws according to the thickness of the cloth to be sheared. This rest-bar is composed at either end of small movable plates or sections, which are brought up to the proper point of contact or removed from it by a system of levers, operated by the fine-toothed wheels shown on either end of the list-rod *D*. These toothed wheels are set at such a distance from the cloth as not to touch the surface of the fabric itself, but so as to be caught and put in operation by the coarse fibres of the thick listing, and by an internal screw on the rod operate the levers, by which the movable ends of the rest are depressed, so as to allow the listing to pass through without being brought in contact with the shear. The *Cotton-Cloth Shearing Machine*, as shown in Fig. 807, has been varied in form, though not in principle, from the original invention of Milton D. Whipple of Lowell. It consisted in holding the surface of the cloth intended to be sheared or trimmed of loose threads or knots firmly against the point of contact of the cutting blades, by means of fixed supports on stationary bars, over which the cloth passed just before reaching and after leaving said point of contact, and a little above its plane. In the modified machine shown, the cloth passes above the cutting blades, and is held down on them by the straining bars, as is seen in Fig. 808, in which *A A* are the rest-bars, *B* the cloth, passing in the direction of the arrow, *C* the revolving cutter furnished with a series of helical blades, and *D* the stationary or "ledger blade" of the shear. This form of machine was intended to clean and trim thin fabrics, like calicoes, mousselines-de-laine, etc., in which the body of the cloth was not of sufficient thickness or elasticity to allow of its being held by a rigid bar directly against the point of contact of the shears; but it has since come into very general use for all cotton fabrics. In the machine as represented, Fig. 807, the cloth enters over the rollers *C*, and is drawn tight by the friction-rod operated by the handle *D*, and passes first over the brush *A*, which serves to raise the nap of the cloth, and also takes up many of the loose ends and threads which are left as it comes from the loom. It then passes over the shear-blades *B*, and in the machine shown to the brush and shear *E* and *F*, which are placed above the cloth, so as to trim both sides. It is then taken by the cloth-roll *G*, which draws it through the machine, and delivered to the winding rolls *H*, by which it is wound into a roll for the folding machine. The dust and lint sheared off are taken away by the fan *J*, through the pipes or trunks *K K*. These machines are varied in construction according to the work to be performed, in some cases having four sets of cutters on one side of the cloth only, in others having cutters on both sides. The pieces of cloth are sewed together by a sewing machine, designed for the

808.

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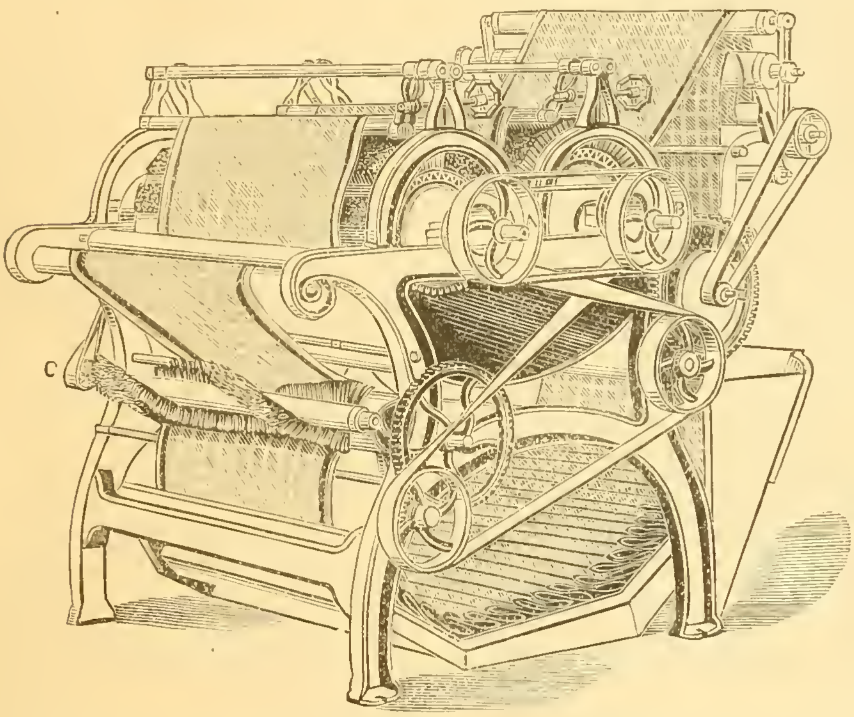


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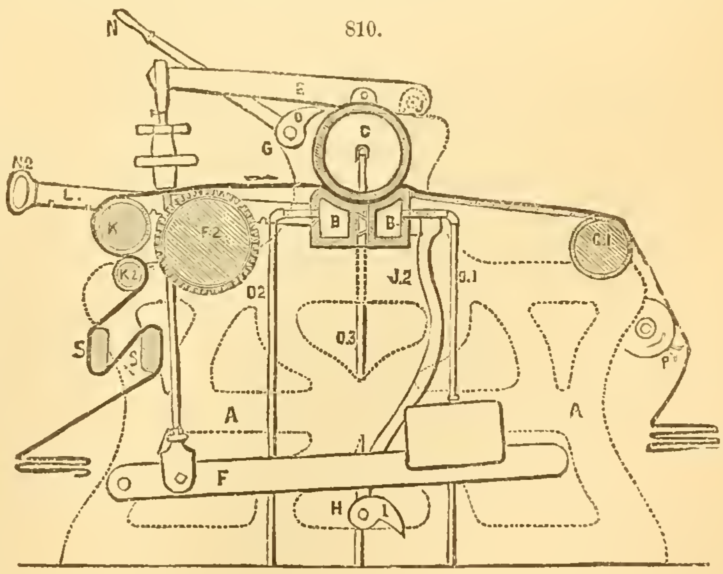
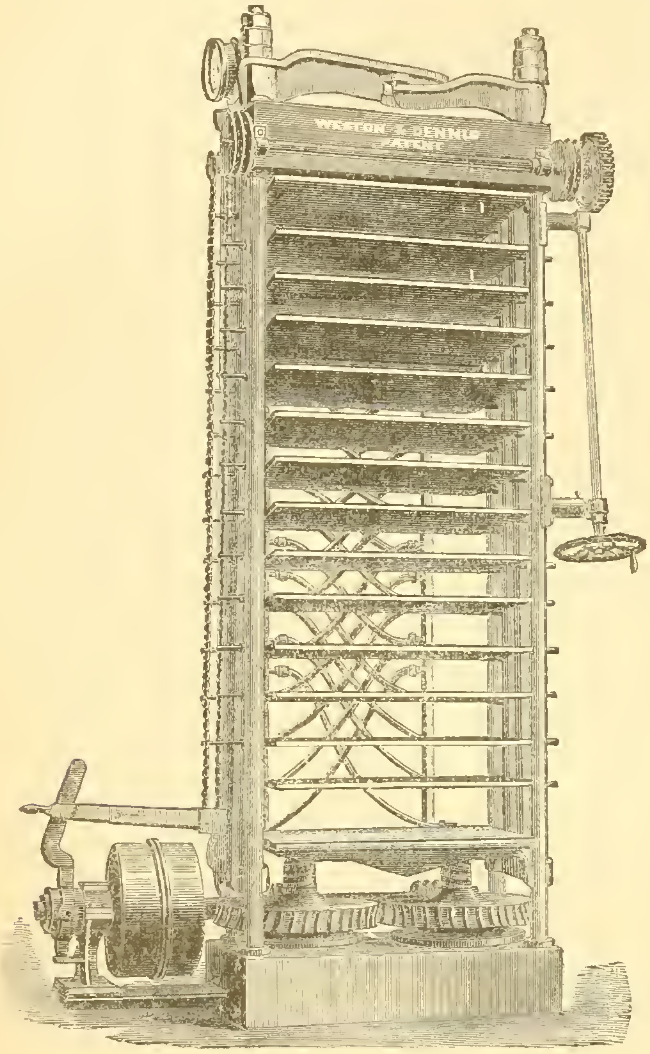


purpose, before entering the shear, so that its operation may not be interrupted at the end of each piece.

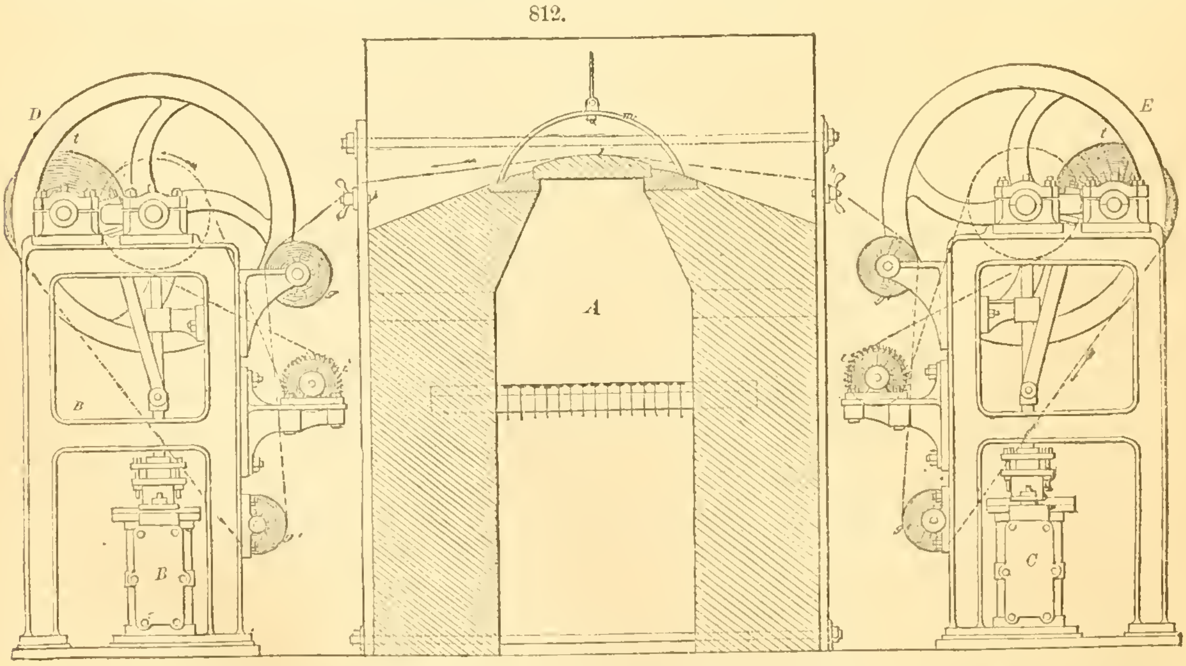
*Brushing Machines.*—For some cotton fabrics a brushing machine is also used. This serves to clean the cloth, and leave it with a slight nap or surface, and is employed for cottonades and goods of a similar description. A brushing machine is also used in the manufacture of many of the finer woolen fabrics, the cloth being alternately "napped" and sheared till the desired surface is attained; and this is completed by brushing. In the machine represented in Fig. 809, the cloth, previously moistened, is submitted to the action of the rotary brushes *A* and *B*, being passed over tension-rollers as shown, in such a manner as to subject it twice to the operation of each brush. The brush *C* serves to clean the back of the cloth from the flocks, etc., left by the shears and other machines. From the brush the cloth is taken to the hot press, which completes the finish.

811.




*Presses.*—Fig. 810 represents the Harwood & Quincy continuous press, which is used for hot or cold pressing or for steaming, with a production of 30 yards in 8 to 10 minutes. The cloth goes direct from the shearing machine to the press, where it is brushed and pressed simultaneously, thus saving much time and labor. The pressure can be regulated at will. The machine weighs 45 cwt., and takes about one horse-power to drive. *A* is the framing; *B B*, a concave bearing made in two halves, one to be used cold and the other hot; *C*, a roller running in the concave bearing; *E*, levers with the fulcrum at *J*; *F*, levers connected with the levers *E*; *G*, a shaft which by means of the cam *O* and the hand-lever *N* lifts the lever *E* and the roller *C*. The shaft *H* and its cam *I* lift the levers *F* and *J* 2. *F* 2 is a revolving brush; *K* and *K* 2, friction-rollers; *C* 1, a roller which takes the cloth off the roller *C*; *P*, an arrangement for plaiting the cloth. One half of the concave bearing *B* is kept cool by means of water carried to it through the pipe *O* 1, while the other half bearing is heated by steam through the pipe *O* 2; the lever *L*, having a handle at one end, is in connection with the lever *J* 2; the roller *C* is heated by a steam-pipe *O* 3;

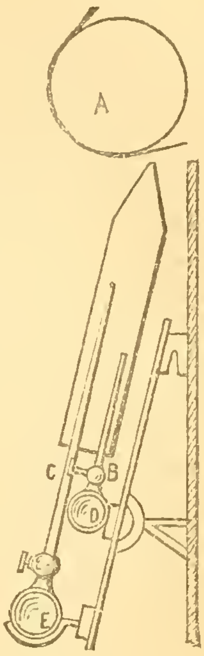
812.




the lever *F* is furnished with a heavy weight. The action of the machine is as follows: The cloth to be pressed passes over the bars *S S* and the friction-rollers *K* 2 and *K*, then over the upper part of

the brush $F$ 2, and thence between the roller $C$ and the concave bearing $B B$, and finally over the roller $C$ 1 and the plaiter. The bearings $B B$ are heated or not as desired. The pressure may be brought by the lever $L$ up to 6 tons. When no pressure is required, but the machine is to be used as a brushing frame only, the roller $C$ is lifted from the cloth by means of the lever $N$. For the purpose of steaming the fabric it is necessary to heat the roller $C$, and to cover it with thick felt.

813.

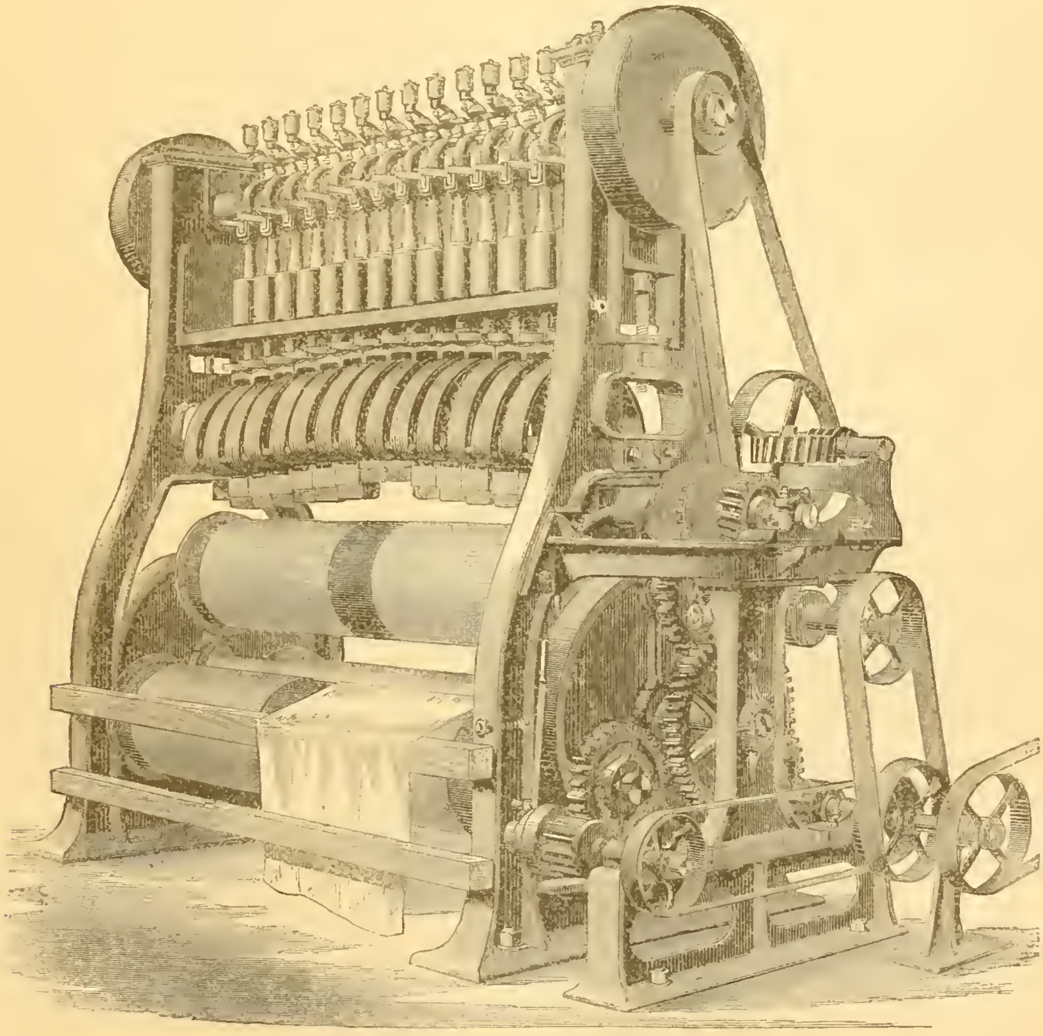



The hollow-plate steam-press, Fig. 811, is used in finishing woolen and worsted goods, which are first folded between smooth pasteboards, called "press-boards," and each piece laid between a pair of hollow iron plates. These are then heated by steam, from jointed pipes connecting each plate with an upright steam-pipe behind the press, and the whole closed up, either by screws or by hydraulic pressure, till the desired pressure and finish are obtained. A uniform heat is secured in this manner, and all the dirt and danger of fire from the old system of furnaces for heating the plates are entirely avoided.

Among other machines used in finishing cotton goods, not above mentioned, is the "napper," used for cotton flannels, which is very similar in its operation to the "gig" used for napping woolen cloths, except that wire card-teeth are used instead of teasels.

*Singeing Machines.*—For the expeditious removal of the flocky and fibrous projections from the surface of cotton stuffs, singeing machines are employed, by the aid of which the flock, etc., is burned off. In Fig. 812 is represented a machine of this description, constructed by the Zittauer Maschinenfabrik und Eisengiesserei of Zittau, Germany. This consists of the hearth $A$ (above which the singe-plate $l$ is placed in a cast-iron frame), and of the brushing and winding apparatus $D$ and $E$, driven by the two small steam-engines $B$ and $C$. By means of suitable clutches the singeing apparatus may be put out of work without stopping the engine. The stuff passes from the cloth-beam $t$ over the rollers $g$, against the brush $i$, and, going over the adjustable knife $h$, passes over the heated plate $l$, whence it finds its way over the corresponding parts of the other machine. If a further singeing is required, the machines are reversed, and the manipulations are repeated, but in the opposite direction. The brush $i$ serves to raise the fibres of the stuff before arriving at the

814.



singeing plate, so that they may be more quickly caught by the heated surface. The cover $m$ is placed over the plate $l$ as soon as the machine is stopped; this is done in order to prevent the

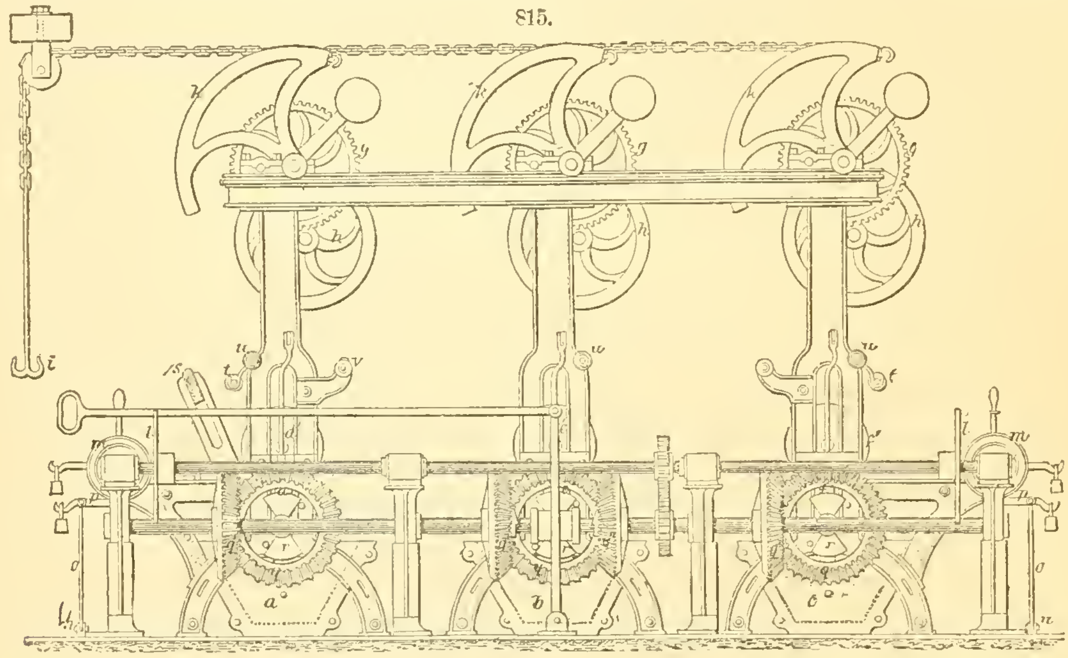
air from coming into contact with the heated plate $l$. The speed with which the stuff passes over the plate varies according to the thickness and condition of the stuff and the temperature in the room.

Fig. 813 represents the burner used in an improved gas singeing machine devised by M. Blanche. $D$ is the gas-pipe and $B$ the gas-burner. $E$ is the air-pipe and $C$ the air-tube. The gas and air mingle in the conical tube shown, and are ignited at its orifice, the flame impinging on the cloth as it passes around the roller $A$.

*The Beetling Machine.*—An improved form of this apparatus, of English construction (Patterson's patent), and exhibited at the Paris Exposition of 1878, is represented in Fig. 814. Its peculiarity consists in its bringing to bear on the cloth a number of hammers or fallers worked at a high speed, these hammers being worked by eccentrics on a shaft which extends across the top of the machine, and there being interposed between the eccentric rods and the hammers a spring connection which relieves the working parts from the recoil of the blows, and materially reduces wear and tear. The spring connection is made by suspending each hammer from a leather belt attached to a semicircular steel spring, as shown. In the old-fashioned beetling machines the hammers or "fallers" were lifted by cams, and allowed to fall by gravity, while the utmost speed at which they could be run was about 60 blows per minute. In the machine here represented the hammers give 420 blows each per minute, while the striking effect of each blow is the same as in the old machine. The hardness of the blow can, however, be varied by altering the speed. The cloth being operated upon is carried by one of three rollers which revolve in bearings carried by disks, as shown, these disks being themselves capable of revolving. The three cloth-rollers can thus be brought successively under the action of the hammers, and the operation of the machine is thereby rendered continuous, the filling and stripping of the rolls not interfering with the beetling.

*Craping Machine.*—Cotton, linen, and half-woolen stuffs are usually soaked with a finishing fluid, in order to procure a certain stiffness, smoothness to the touch, and often lustre. In order to do

815.

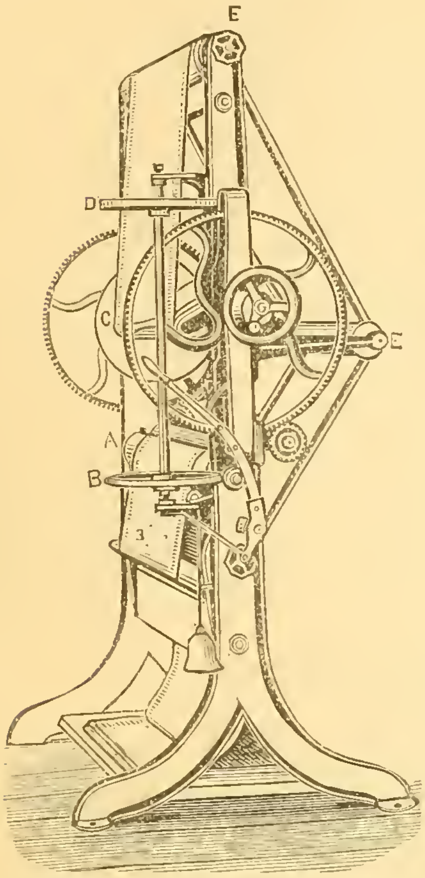


this in a suitable and uniform manner, special machines are used. Starching machines, which may either be fixed to the cylinder drying machines, or may be used as independent machines, belong to this class. Craping machines are generally used for effecting a continued washing, boiling, and rinsing of woolen or half-woolen stuffs in an alkaline solution, for the purpose of finishing, or as a necessary preparation for the process of drying, or to provide the stuffs after being cleaned with finishing matter. This machine is an important element in the finishing process. As will be seen from Fig. 815, it is provided with three boxes, $a$, $b$, and $c$, which contain the different fluids to be used for the finishing of the stuff or for the removal of impurities, such as fat or grease, from it. Three rollers, carried in strong frames, and running against a series of pressing or squeezing rollers $d'$ $e'$ $f'$, project partly into these three boxes $a$ $b$ $c$. These rollers and boxes may be used in various ways, according to the quality of the stuff; thus the latter is either wound round the rollers, which are fixed in such a manner that the stuff is saturated by the fluid, while the rollers rotate and the squeezers partly press the fluid into the material, and partly squeeze it out of it, or the stuff is placed in the fluid, and is simply passed through the squeezers. By means of the wheel-gear $g$ $h$ at the top of the frames, the upper rollers or squeezers $d'$ $e'$ $f'$ can be lifted, in order to afford space for the winding of the stuff around the lower rollers. The shafts of wheels $g$ $g$ $g$ are provided with sectors $k$ $k$ $k$, over which a chain is passed carrying at its end the rod and hook $i$, from which weights of various sizes, according to the requirements of the case, are suspended in order to press the rollers $d'$ $e'$ $f'$ firmly against the lower rollers. The material, which may be passed in or out of the machine from either side, is, after coming from the squeezing rollers, wound upon copper steam-rollers by means of the friction-gear $l$ $m$, which allows the speed of the steam-rollers to be exactly regulated as required, by moving the disk to the necessary distance from the centre of the disk $l$. By means of the foot-boards $n$, the rods $o$, and the levers $p$, the workman at the machine can instantaneously stop the winding up of the stuff by throwing the friction-disks out of gear. Motion is transferred

to the rollers by the bevel-wheels $q\,q'\,q''$, and each pair of rollers can be worked or put out of gear independently of the other rollers by means of suitably arranged couplings $r$. By means of the wooden rails $s$ the stuff is guided into the machine without any folds; $t\,t$ are guide-rollers, and $v\,v$ and $u\,u$ are stretching rods for the different boxes.

*The Measuring and Winding Machine*, Fig. 816, from the Parks & Woolson Machine Company, is of a kind generally used for putting up a large class of narrow woolen and worsted fabrics, which

816.

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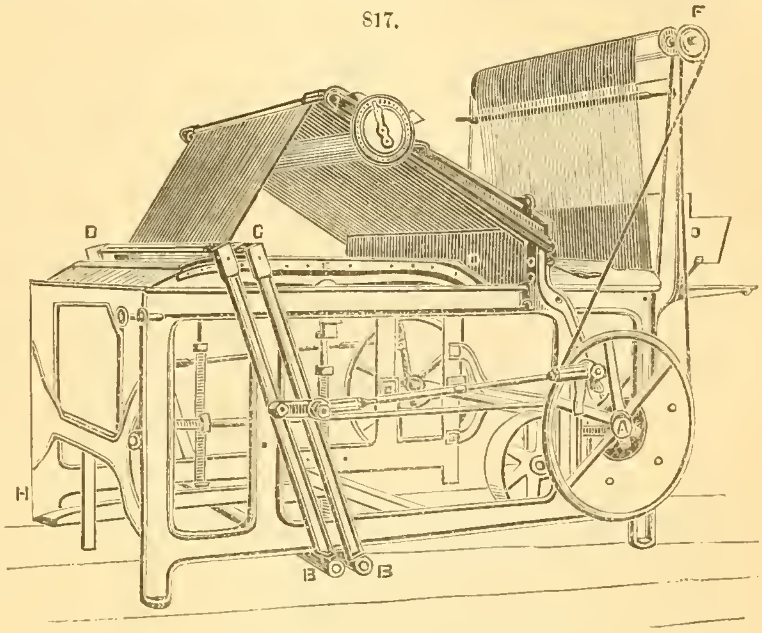
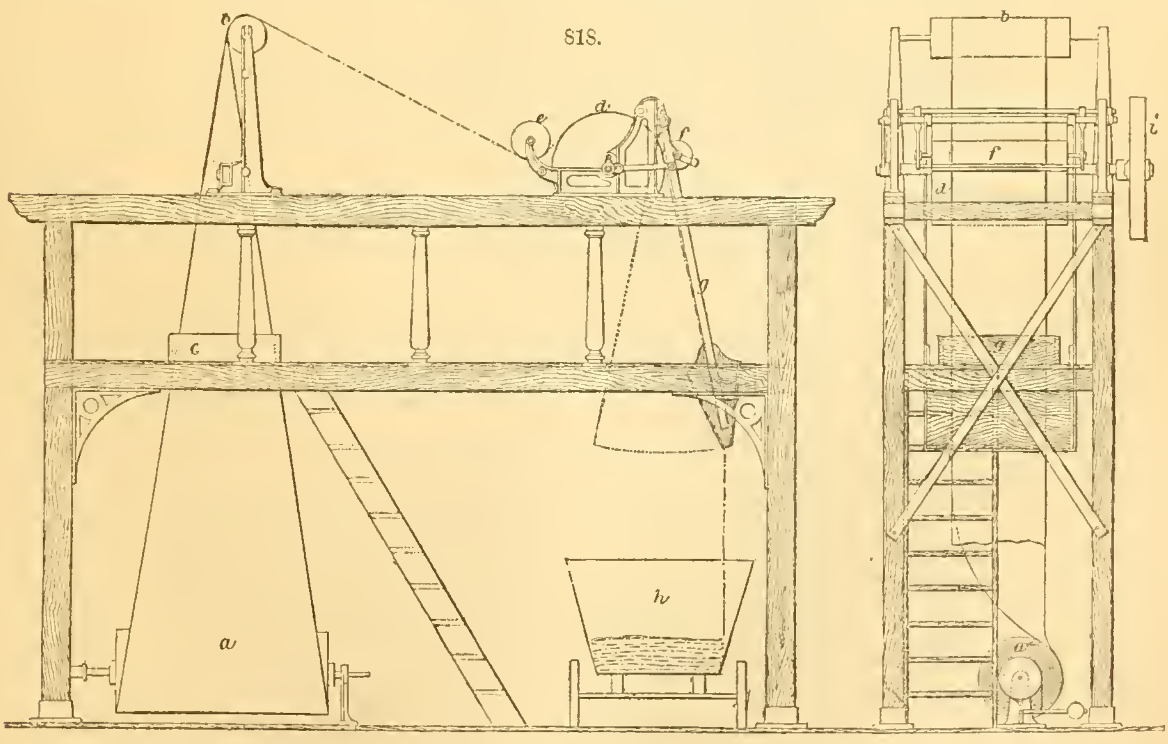



are "rolled" or wound on boards. The cloth passes through proper guides to the measuring roller $A$, having a cloth surface, a worm-gear on the end of which operates the gear of the index-shaft $B$, and records the revolutions of the measuring roller, in yards and fractions, at the index-dial $D$. Passing partly around the measuring roll, so as to give it motion, the cloth is led around the tension-rolls $E$ and $F$ to the winding jaws $C$, which inclose between them the board or slat on which the cloth is to be wound. One of these jaws or clamps is movable, and is operated by a screw connected with the hand-wheel shown, so as to clasp and release the board at pleasure. After each piece is rolled and measured, the index-plate is thrown out of gear, and reset at zero for the next piece.

818.

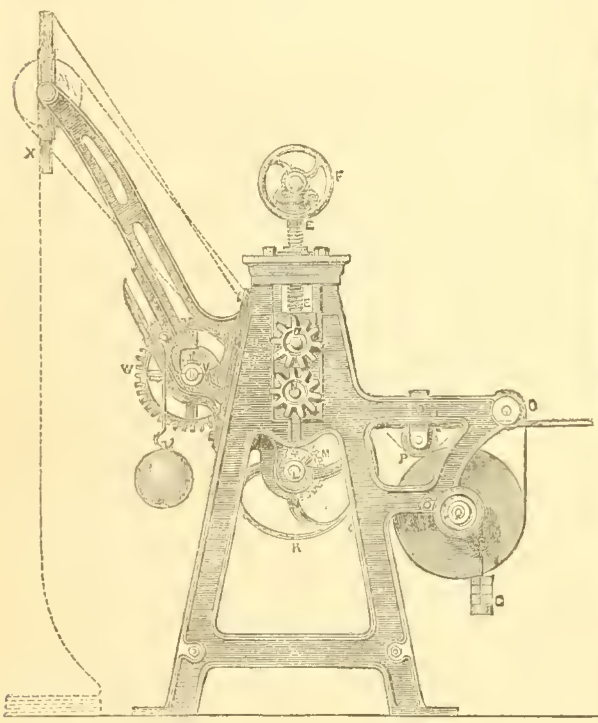



*The Cloth-Folder*, Fig. 817, is widely used for cotton cloths, prints, and other light fabrics. The crank-disk $A$, on the main shaft, gives motion to the two parallel levers $B\,B$, supported on a stud, and connected at the top by a funnel-shaped mouth-piece at $C$, through which the cloth is brought from

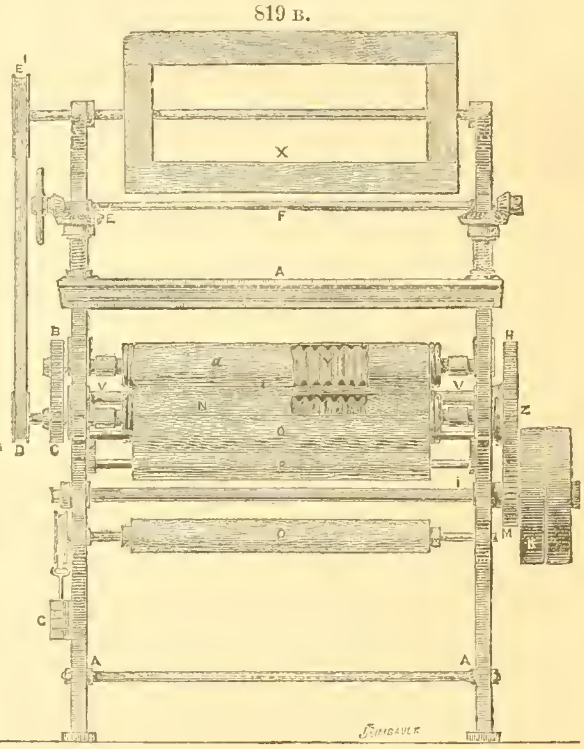
the delivery roll $F$. This mouth-piece is inclined alternately to the right and left by the motion of the bars $B\ B$, so that the lower edges of it insert the cloth between the stationary bars $D\ D$, the under faces of which are covered with card-teeth, and the floating table $E$ supported by springs, which yield sufficiently to admit of the entrance of the edge of the mouth-piece with a thickness of cloth at each vibration of the same, and retain the fold as the mouth-piece is withdrawn. When the piece is folded, and at the same time measured, a pressure of the foot on the lever $H$ drops the table $E$, and admits of the removal of the cloth. Another form of folding machine, of German construction, is represented in Fig. 818. It consists of a frame about 14 feet high, carrying at the bottom the cloth-beam $a$, from which the stuff passes half folded to the roller $b$, and thence to the rollers $e$ and $d$. The stuff is pressed against the cylinder $d$ by the roller $f$, while the laying down into the trolley $h$ is effected by the lever $g$ worked from the shaft carrying the pulley $i$.

*Stretching Machine.*—During the process of drying the maintenance of the stuff at its correct width is of great importance, and always has been a difficult matter on account of the shrinkage which takes place. Side and front elevations of a machine devised by J. Ducommun & Co. of Mulhouse are given in Figs. 819 A and 819 B. It consists of fixed and solid frames $A$ carrying the main shaft $I$ with the pulleys $K$ and the spur-wheel $M$, which transfers the motion by means of the wheel $Z$ to the roller $N$, the latter being geared to the second roller $a$ by the pinions $C$ and $B$. These stretching rollers appear cylindrical externally, as shown in the engravings, but they consist of an India-rubber tube drawn over a grooved core, as shown at $Y$ in Fig. 819 B. These cores of the two stretching rollers are arranged in such a manner that the grooves of the one correspond in position and shape with the projections of the other roller; this cannot be seen, however, unless the

819 A.



819 B.



two rollers are pressed together by means of the screws $E$, worked by the shaft $F$, when the grooves are shown through the India-rubber tube. The stuff $R$ is unrolled from the roller $Q$, and passes over $O$, under $P$, and over the elliptical roller $T$; it is taken up either by the laying or distributing apparatus $X$, or by the roller $V$, in which latter case it has to pass the table $U$, and is stretched during winding up by the roller $W$. Even a superficial examination of the rollers $a$ and $N$ will show that the stuff passing between them must be stretched. The machine also effects the breaking up of the finishing matter, and makes even very strongly finished stuff soft to the hand. (See *Engineering*, xv.) S. W. (in part).

CLUTCH. See COUPLINGS AND CLUTCHES.

COAL. See BOILERS, STEAM.

COAL-BREAKER. See BREAKER OR CRUSHER.

COAL-CUTTING MACHINES. Apparatus used for effecting mechanically the separation of the coal from the inclosing rocks. The value of machinery for this purpose over manual labor consists in the greater rapidity with which the work is executed, and the smaller waste that is made in the operation, so that the production of a given quantity is obtained at a much less cost than by hand. The coal itself is also brought down in much larger pieces, while the danger incident to "holing" by hand is altogether removed. One of the principal drawbacks, however, appears to be the cost in the first instance of conducting the motive-power, which is derived from compressed air, from the surface to the workings below.

Gladhill's machine (English) acts on the coal by means of an endless chain armed with teeth or blades, revolving around a shive or solid plate secured over the coal. The apparatus is driven by compressed air brought from the surface through pipes, under a pressure of from 35 to 40 lbs. per square inch. The chain consists of flat links, each link being enlarged at one end for the purpose of holding the blades. The chain is made of cast-steel, and the width of each cutter is $2\frac{1}{2}$ inches.

The machine advances automatically in proportion to the clearing of the coal by means of capstans, placed at both the forward and after ends of the frame, so as to work both ways. The inventors claim that it will advance 300 to 350 feet with a depth of 3 feet in 8 to 10 hours, producing 75 to 90 tons of coal, assuming the vein to be $2\frac{1}{2}$ feet thick. The movements of this machine are not, however, adapted to the undulations and irregularities found in most coal-mines.

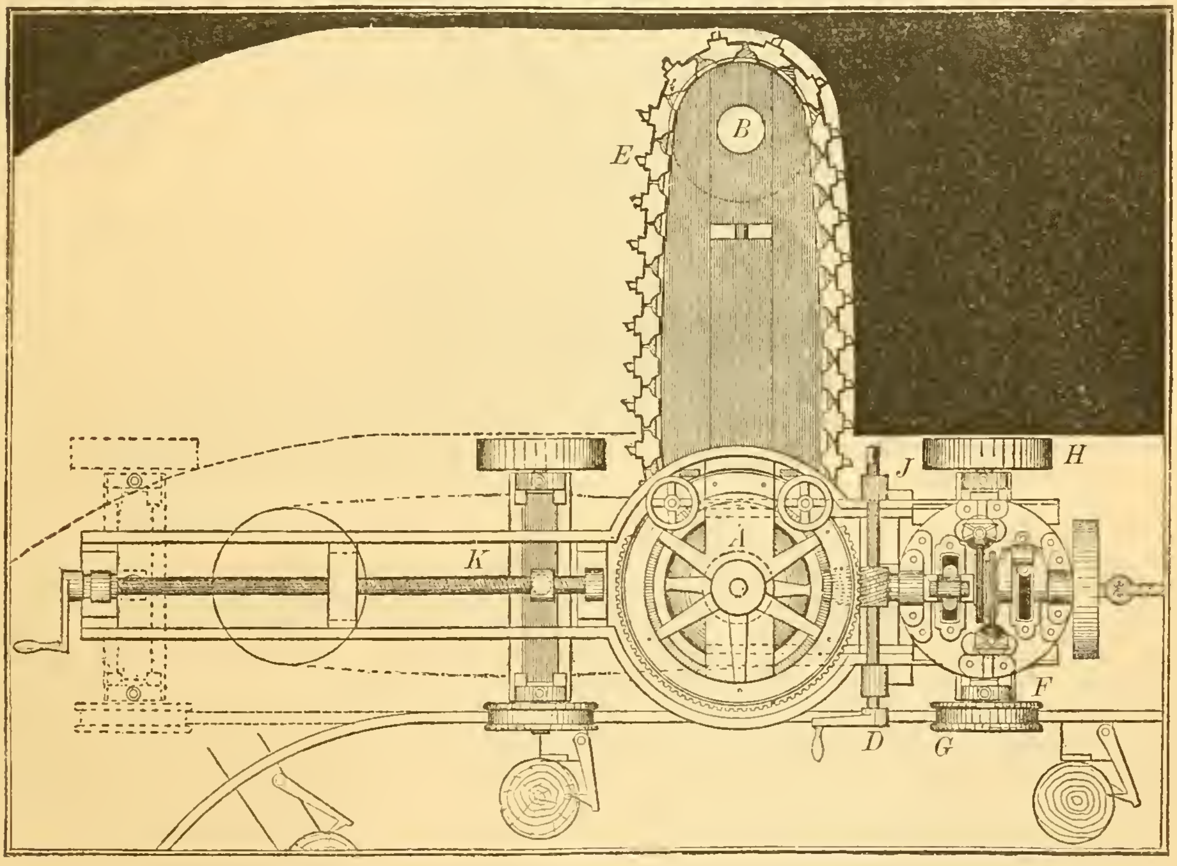
Holmes & Payton's machine (English) has for its cutting tool a strong steel blade, which is attached to two eccentrics in order to give it rigidity; the teeth are inserted in the plate and operate like picks, each tooth advancing on the same plane and describing circles according to the impulse of the eccentrics. The length of the plate is 3 feet. The teeth of the cutting blade act by blows, as do the picks used in hand labor. About 300 blows per minute are struck, and the opening of the cut is from three-fourths of an inch to one inch to a depth of 3 feet. The inventors claim an advance of 8 to 12 inches per minute, according to the hardness of the rock or coal.

For complete descriptions of this and the foregoing machine, see "Reports of Judges of Group 1, Centennial Exposition, Coal-Mining Machinery," by A. Jottrand.

Firth's machine, used in the mines of the West Ardsley Coal and Iron Company, near Leeds, England, consists of a pick worked by a bell-crank lever, the action being exactly the same as that of a miner when engaged in undercutting.

There are also various forms of rotary machines. In Hurd's machine a number of steel cutters or teeth are placed on an endless chain or band, moving longitudinally around a long arm. These cutters form a groove in the coal. This apparatus is reported to have worked in a 20-inch seam, making a semicircular sweep of 6 feet 6 inches in 4 minutes, with only 25 lbs. pressure on a 6-inch cylinder with 6 inches stroke, cutting a groove of $1\frac{1}{4}$ inch. The Monitor coal-cutter, Fig. 820, is one

820.

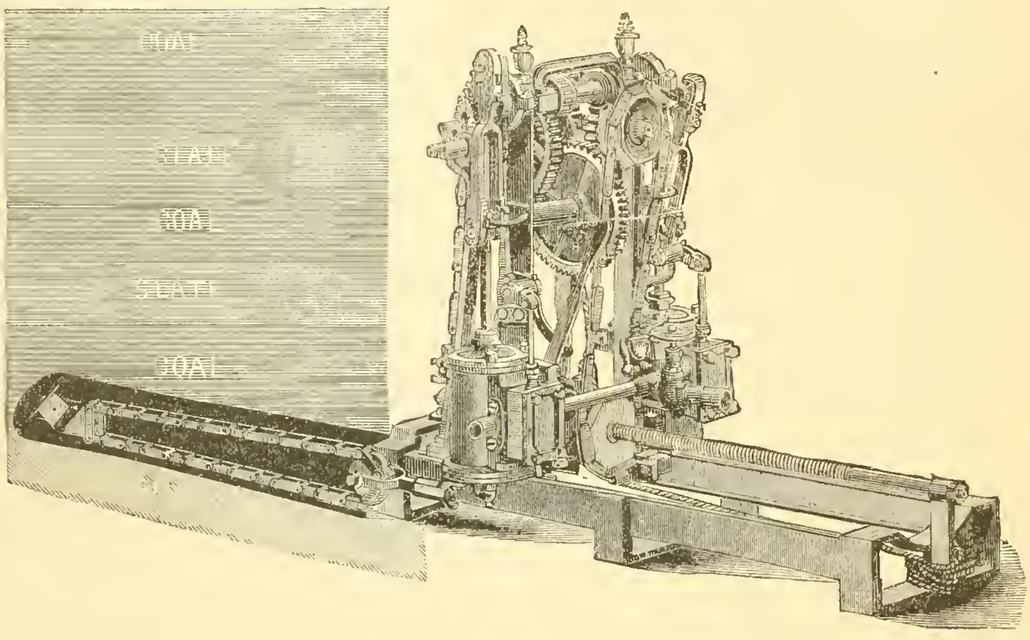



of the latest forms of this type of machine. *A* shows the inner and supporting part of the cutter-arm; this is joined to the frame *D* by means of a pivot-hinge that holds the arm horizontally, but allows it to be raised or depressed on either edge, by means of which the cutter can be made to lead up or down in the coal, to follow the irregularities of the bottom, to avoid interlaminated strata of rocks, etc. The arm can also be raised or lowered without otherwise changing its relative position to the machine. *B* is the outer portion of the cutter-arm, and is geared to *A* in such a manner that it can be thrown out or in to lengthen or shorten the arm as required. Attached to *B* is the wheel that acts as a carrying wheel for the chain *E* at the outer extremity of the arm; at the other end of the arm, and attached to a shaft, is a similar wheel that acts as a driver for the cutter-chain. *F* is a double-cylinder vertical-trunk engine, 8-inch bore and 7-inch stroke. The whole is attached to the framework *J*. This, in turn, is supported by the wheels *G*, *H*, etc. The wheels are all plain flanged wheels, as shown by *G*. While working, the machine requires but one rail of the common T iron, 9 lbs. per yard. The forward wheel is kept on the rail by means of the second flange *G*, which is slipped on and held by means of thumb-screws. The other two wheels are rimmed into the broad flanges *H*, made in two more sections, which run directly on the bottom. When in shape for moving, the wheels *G H* are drawn to the end of the frame *J* by the screw *K*, and the cutter-arm swings under the frame *J* by means of the screw-shaft *D*, which engages the teeth of the segmental

gear attached to the frame *J*. The machine is fed forward by means of a power windlass, operated by air. The windlass consists of an upright drum, driven by a small rotary engine, so geared that it will wind slowly enough for the lightest feed, or fast enough to pull the machine up the grade from the gangway very rapidly. The feed can be varied instantly by the throttle-valve to suit the varying strata that are being cut—a useful advantage, as in many places in the same breast one yard can be cut in half the time with the same power that it would require to cut the next yard. The capacity of the machine, of course, varies greatly with the nature of the material cut. The following will show what the machine is stated to have accomplished in what is about the average hardness of splint coal: Weight of machine, 3,800 lbs.; depth of cut (extreme), 4 feet; depth of cut (average), 3 feet 6 inches; thickness cut out, 2 feet 6 inches; pressure used per square inch, 25 lbs.; cut along face (average) per hour, 20 yards; space between props and coal, 42 inches; gauge of track, 29 inches. Exceptional work, 15 yards in 20 minutes; 30 yards in 55 minutes; 5 yards in $4\frac{1}{2}$ minutes.

The essential features of the Lechner coal-cutting machine, Fig. 821, are the cutter-bar and the modes of driving it. The cutters in this case revolve in a vertical plane. The form of the axle is square, and motion is communicated to it by a couple of pitch chains, which not only drive by contact with the axle itself, but also by engaging a set of narrow cutters, which enter the open portions of the chain. In this manner only thin films of coal are left uncut where the chains work, and get broken off quite imperceptibly by coming into contact with the links of the chain. In addition to the wrought-iron bars which form the framing to which the cutter-bar and the driving gear are

821.



attached, another set of similar bars at the side of them form the stationary framing on which the whole machine slides. The forward motion is given by means of a stationary screw, round which a nut revolves, and this motion is arrested by moving a handle which separates the two halves of the nut in a similar way as the screw and nut are disconnected in most screw-cutting lathes. To bring the machine back again, a bolt attached to the stationary framing is, by means of a handle, thrown into gear with one of the pitch chains, which are kept revolving to clear away the dust. Either steam or compressed air can be used for driving, motion being communicated by suitable means from the pair of cylinders to the pitch chains. The machine weighs 750 lbs., and can be handled by two men. The cut which it makes is 6 feet deep, 3 feet wide, and 4 inches high.

COFFER-DAM. See Foundations.

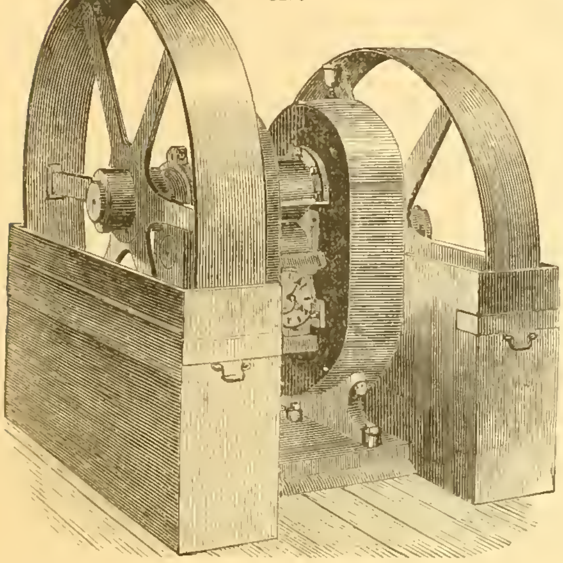
COGGING. See Carpentry.

COG-WHEELS. See Gearing.

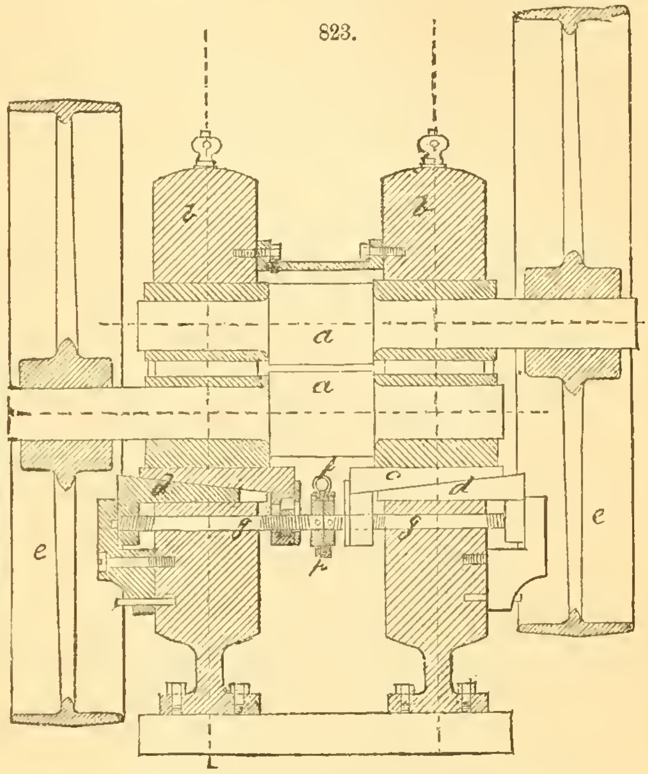
COINING MACHINERY. Gold and silver in their pure state, on account of their softness, are unadapted for coin; consequently, each metal is alloyed with a certain quantity of some baser metal, to give it greater hardness and durability. In this country, silver in the manufacture of silver coin is alloyed with copper, the proportion in 1,000 being 900 parts silver and 100 parts copper; and in gold coin 1,000 parts, 900 being pure gold, 100 alloy of silver and copper, of which not more than 50 parts is allowed by law to be pure alloy. In United States mints the following is the process of manufacture: By means of powerful but accurately constructed rollers driven by steam, the ingots (which are bars sharpened at one end like the blade of a chisel, and about 1 foot long, three-quarters of an inch to $2\frac{1}{2}$ inches broad, and three-sixteenths of an inch thick) are rolled into thin strips for the coin to be made. Fig. 822 shows the rollers in perspective, and a sectional view is given in Fig. 823. The rollers *a a*, of chilled cast-steel, are set in a strong cast-iron frame *b b*, and are capable of very minute adjustment by means of the wedges *c d*, actuated by the double screw *g* through a worm *f* and wheel *p*. They are driven in opposite directions by pulleys *e e*. As the effect of rolling is to harden the strips, they are packed in bundles in copper boxes and placed in an annealing furnace. When red-hot, the boxes are withdrawn and their contents emptied into cold water. A pair of cast-steel finishing rollers next reduce the strips to their required thickness, when the jagged ends are cut off by shears and returned to the melting-rooms. After a sec-

ond annealing, the strips are pointed by slipping them between rollers *a a*, Figs. 824 and 825, while a passage is formed by one of the depressions *e e* on the lower roller. The face *f* reduces the thickness of the strip end about one-fifth. When a strip is too heavy after rolling, it is reduced to its standard between the dies of the *draw-bench*, Fig. 826. The previously pointed end of the strip is

822.

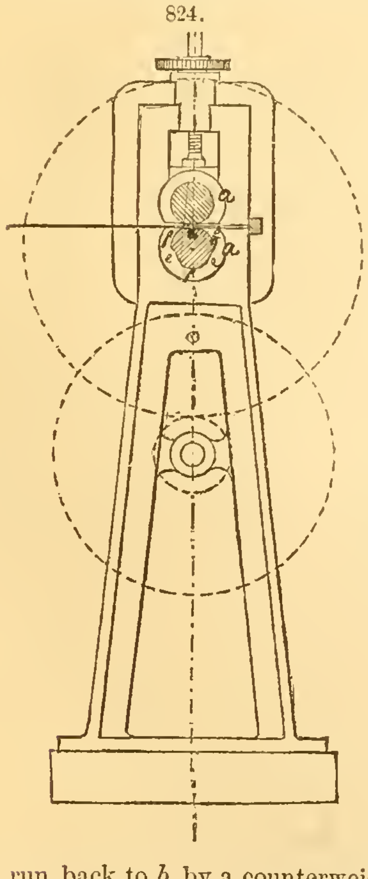


823.

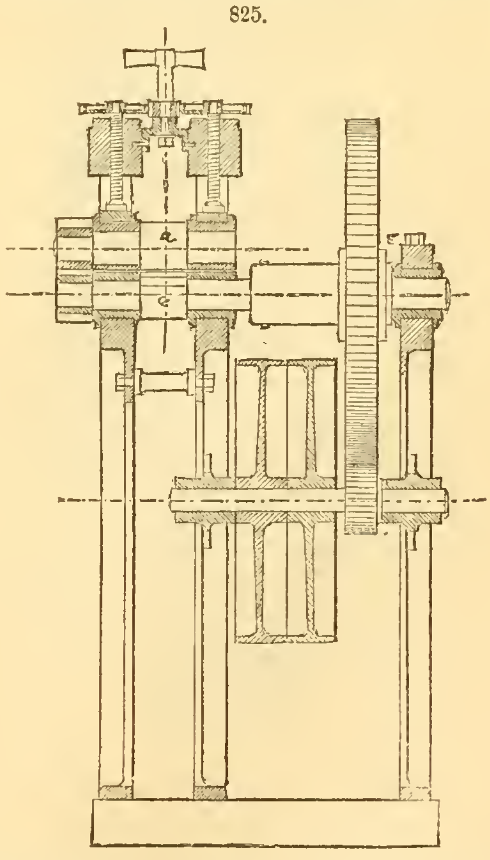



slipped between the dies at *a*. The operator then places his hand upon the carriage *r*, which is at *b*, close to the die, and by stepping upon the treadle *c* causes the hook *h* to grasp the moving endless chain *d*, whereby the jaws *e* grasp the projecting end of the strip and draw it through the dies. As soon as the strip has passed the die, the jaws open, the hook *h* releases the chain, and the car-

824.




825.



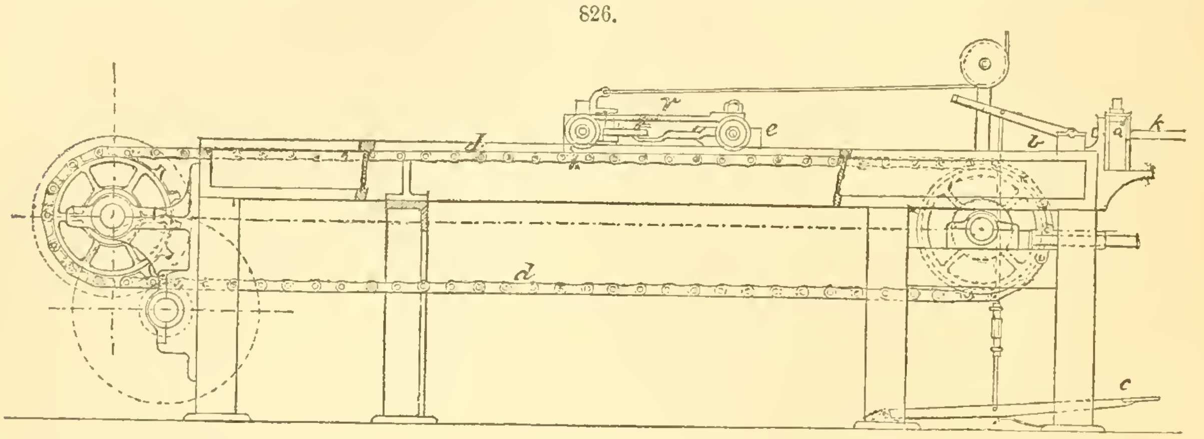
riage is run back to *b* by a counterweight. The dies consist of two pieces of polished steel, adjustable in the head-block *a*. The lubricants used for the strips are wax for gold and tallow for silver.

*Blanks* or *planchets* are next cut from the strip by means of the cutting-presses shown in Figs. 827 and 828. A vertical steel punch, working accurately into a matrix or round hole in a steel plate of

the size of the planchet required, is operated rapidly by an eccentric, under which the strips are fed by hand. In Fig. 828, *a* is the punch, *b* the bolster, *c* the detaching ring, and *d* the discharge tube. The punch-frame *g* is raised and depressed by the crank-shaft, which makes from 140 to 220 revolutions per minute. The first blank from every strip is weighed, and if found too light is condemned, while the succeeding blanks from the same strip receive greater weight by being made slightly cup-shaped by a peculiar adjustment of the punch. Blanks and strips are cleaned by dipping in an acid bath, hot-water bath, and soap-water bath. Blanks receive a final cleansing by shaking with sawdust in a hand-riddle. Blanks for silver dimes and half dimes are cleansed in a revolving steam-riddle.

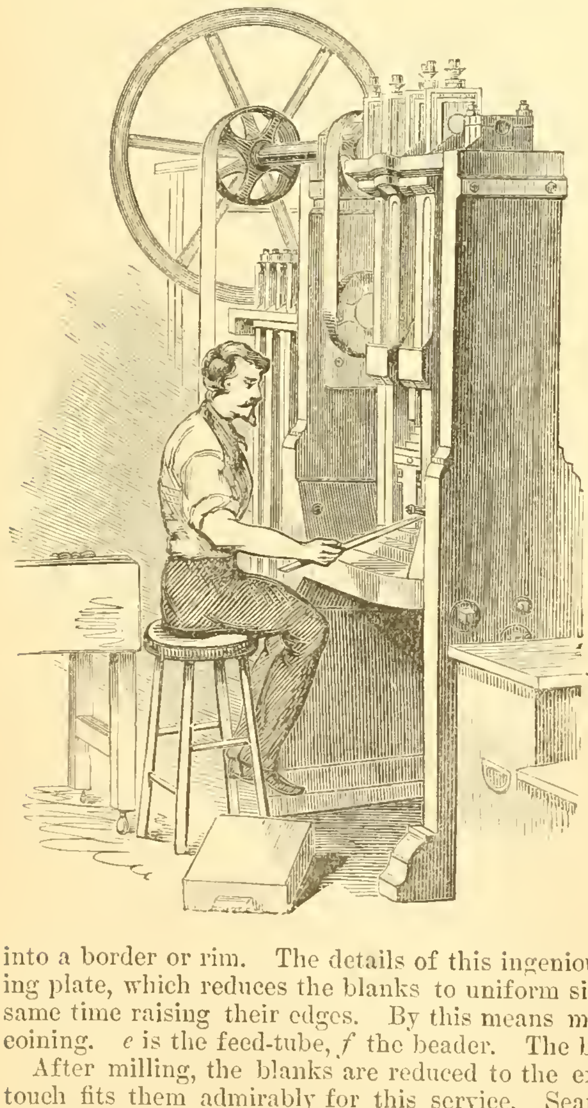
The blanks are now placed in the *milling machine*, Figs. 829 and 830, by which, as rapidly as they

826.

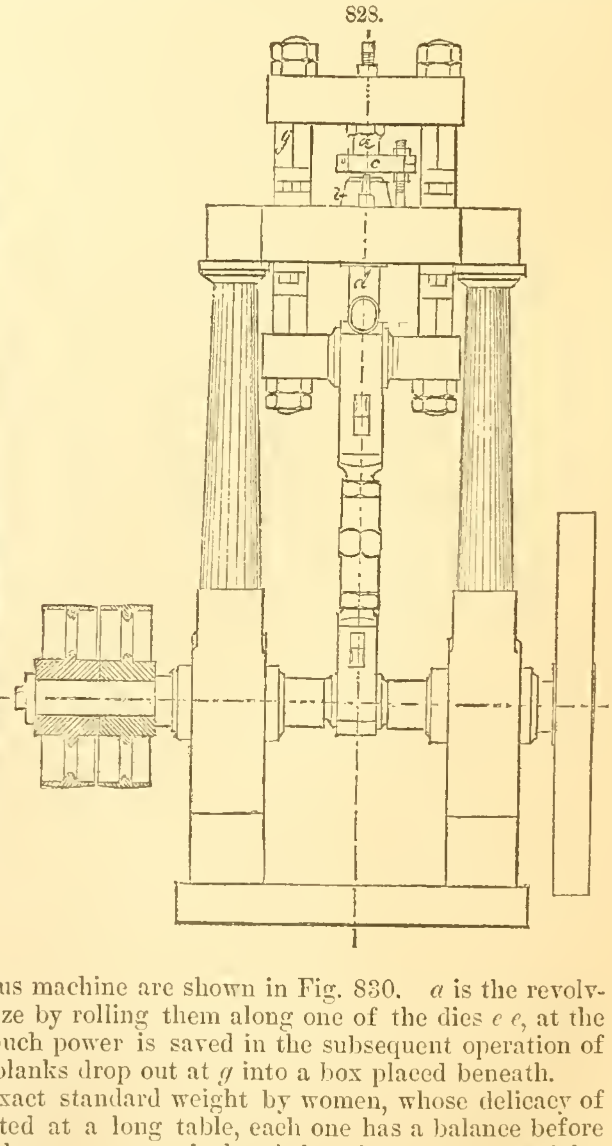


can be fed by hand into a vertical tube, they are caught one by one edgewise, and caused to rotate in a horizontal plane in a channel formed on one side by a revolving wheel, and on the other by a fixed segment of corresponding curve, but slightly nearer the wheel at one end than at the other. The effect is that each piece in passing through this narrowing channel has its edge evenly crowded up

827.



828.



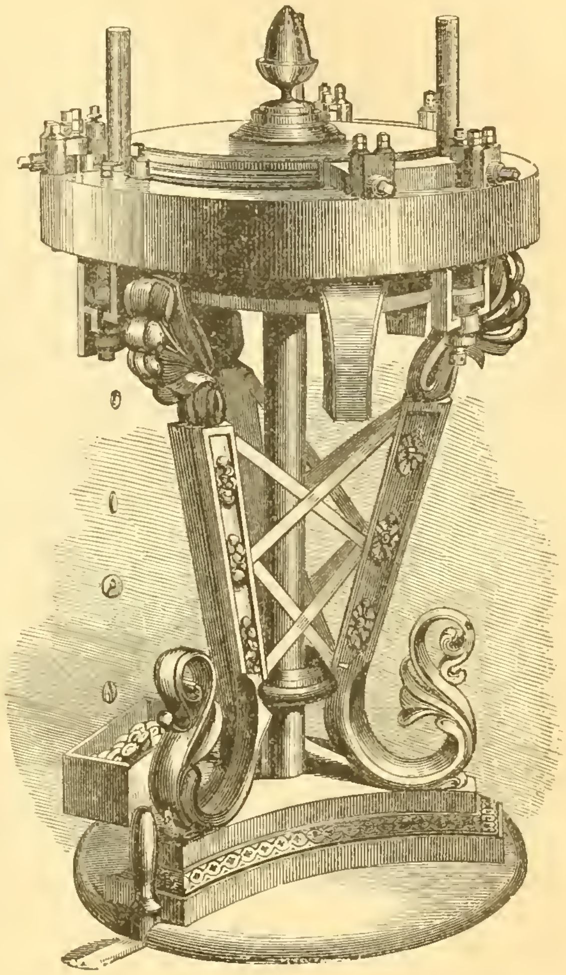
into a border or rim. The details of this ingenious machine are shown in Fig. 830. *a* is the revolving plate, which reduces the blanks to uniform size by rolling them along one of the dies *c c*, at the same time raising their edges. By this means much power is saved in the subsequent operation of coining. *e* is the feed-tube, *f* the beader. The blanks drop out at *g* into a box placed beneath.

After milling, the blanks are reduced to the exact standard weight by women, whose delicacy of touch fits them admirably for this service. Seated at a long table, each one has a balance before her and a flat file in her hand, and the gold planchets are successively tried against a counterweight.

Those that are too light are thrown aside to be remelted, and those that are too heavy are brought to the proper weight by moving the file lightly round the edge.

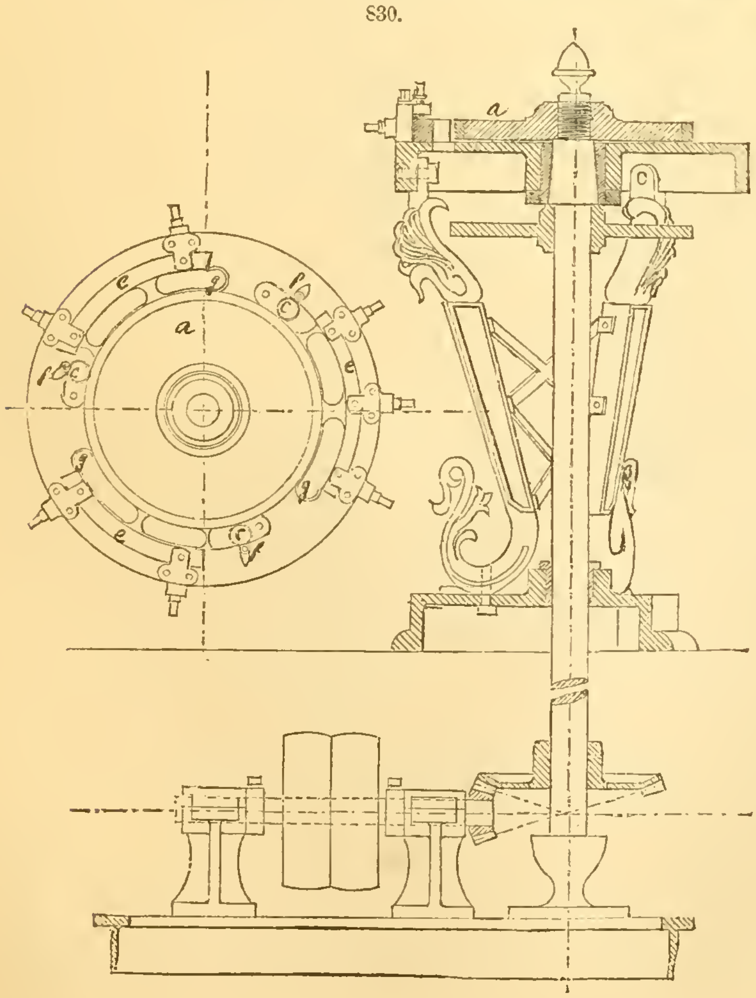
The *coining press*, Figs. 831 and 832, in use in all the mints of the United States, is constructed after the plan of the French lever press invented by Thonnelier. The pressure upon the die is effected by a lever moved by a crank and operating a toggle-joint. The planchets being fed by hand into a tube or hopper *a* in front of the machine, the lower piece in the tube is seized by steel feeders and carried forward and lodged in the collar between the upper and lower dies *g*. At the same moment the lever is descending, and by the time the planchet is in position the toggle-joint, brought into a vertical position, imparts to the piece a pressure which, within the narrow limits of its motion, is very great. The immediate relaxation of the joint causes the upper die to be lifted, when the feeders, coming up with a second planchet, push away the one already coined. The planchet before being struck is slightly less in diameter than the steel ring into which it drops; but the pressure upon the dies causes the piece to expand into the collar and take from it the reeding or fluting of its edge. The toggle-centres *d d* are made of tempered steel. *c* is the main lever, *e* the toggle-post, *f* the crank-shaft, and *m* the connecting-rod. The coins, after being carefully inspected to eliminate defective pieces, are put up in bags and delivered to the mint superintendent.

829.

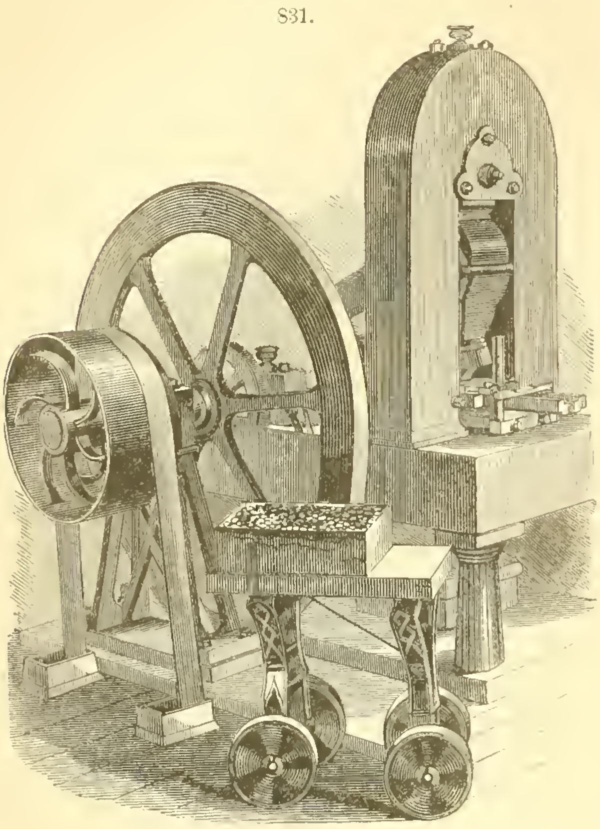


In European mints the ingots are passed first through roughing and afterward through finishing rolls, which latter reduce the fillets to their exact thickness. Generally the finishing rolls are of a diameter smaller than the breaking-down rolls; in Brussels, however, the latter are only 6 inches in diameter, and the former are 9 inches. At Stockholm, in reducing silver into fillets, the bars are placed hot in the rolls, which are made hollow, and kept cold by streams of water passed through them. The subsequent process of fine rolling is performed when the metal is cold. At all the European mints an accurate mechanical arrangement for adjusting the space between the rolls is employed, consisting of screws with finely graduated index-plates, and in some cases of a combination of them with a wedge adjustment. In most cases the rolls are driven with toothed gearing. At Vienna and Brussels, however, they are actuated by belting to avoid the irregular motion sometimes imparted by the toothed gearing, and which affects the accuracy of the fillet. Before being stamped into blanks, the fillets undergo in most of the mints a further process whereby they are brought to a perfectly uniform thickness. The final adjustment is obtained by drawing the fillets between smooth parallel jaws, placed at an exact distance apart by means of a gauge. Except at Brussels, the fillets hard-

830.



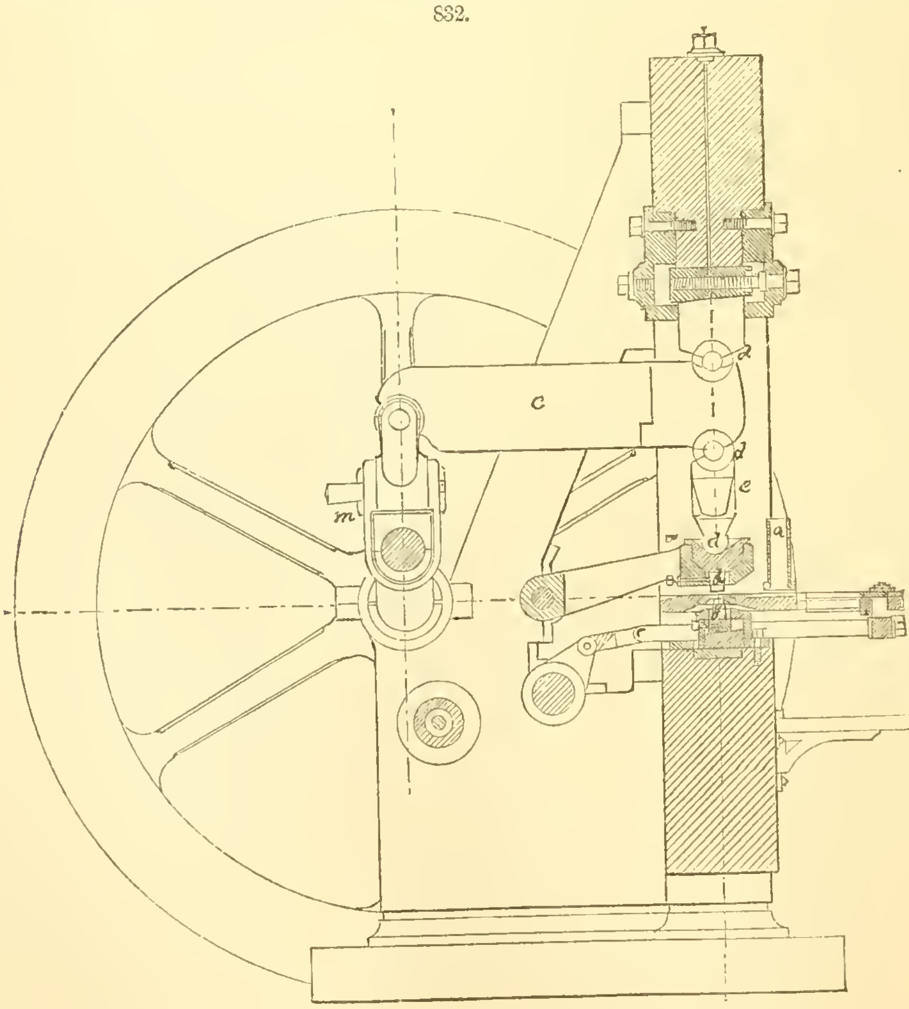
831.



ened by the rolling process are annealed more or less frequently for the purpose of softening them. In England they are placed in copper tubes, covered and luted with clay, inserted in a reverberatory furnace, and then rapidly cooled. Fig. 833 represents the English annealing furnace, with the copper cells resting on their carriage. In most mints a reverberatory furnace is employed, the fillets being laid on the floor, which may be slowly revolved so as to submit the whole charge to equal heat, the flame passing through an opening into the chamber where the fillets are laid.

Except at the English and Danish mints, screw-presses for stamping the fillets into planchets are not employed. These are arranged in a circle around a large wheel, in the periphery of which cams are placed to actuate the presses, in connection with vacuum cylinders provided for each press. The crank-presses in general use on the Continent consist of a vertical frame, with a crank-shaft overhead which drives a connecting-rod that is attached to the punch-slide, and to which it imparts a reciprocating motion. The fillets are for the most part led forward into the press by a self-acting feed. On the Continent the blanks are all weighed. The weighing machines at St. Petersburg consist each of 10 balances with feeding tubes for supplying the blanks. Through these the blanks are laid upon the scales, which are depressed in proportion to the weight upon them; and from the scale they are ejected by an automatic arrangement into one of three openings ranged one above the other, for the reception of the too light, the too heavy, and the correct blanks. In Stockholm and Copenhagen an

832.




ingenious arrangement is in use. The counterpoise of the balance consists of a horizontal ring 4 inches in diameter, which rises and falls freely in a tube, and over which is stretched a diaphragm of gauze; when the blanks are weighed and the counterpoise raised, the resistance offered by the

air to the fabric-covered ring causes the beam to dip more or less, the angle being registered by an index and graduated scale.

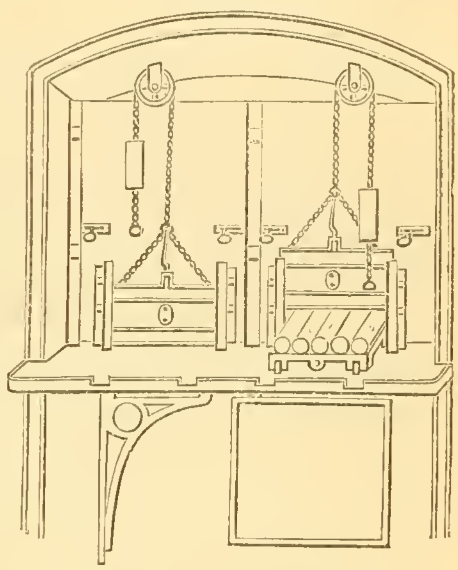
*Standard and Least Current Weights.*—The standard weights and least current weights of gold coin are as follows:

| | | | | | | |
|---|---|---|---|---|---|---|
| 20 dollar piece—standard, | 516 grains; | least current weight, | 513.42 |
| 10 " | " | 258 " | " " | 256.71 |
| 5 " | " | 129 " | " " | 128.36 |
| 2½ " | " | 64.5 " | " " | 64.18 |

Any decrease in weight below the latter figures subjects the holder to a loss equivalent to the difference.

*Counterfeit and Spurious Coins.*—The most extensive fraud perpetrated on gold coinage is "splitting." The operator uses a fine saw to split the coin neatly in two. Then he gouges the gold out of the centre until only a thin outside shell is left, and substitutes a silver and platinum alloy for the metal thus abstracted. The two parts are then joined with gold solder, and the edge is remilled. In this way gold to the value of $15.50 has been taken from a single piece. The operation, however, generally destroys the ring or tone of the coin, leaving it, besides, either too light or too thick. Boring into the edge is another method. The holes whence the gold is taken are refilled with silver, covered with gold solder, and the edges are neatly finished; but the light weight reveals the theft. From 5 to 7½ dollars' worth of gold has thus been taken from one coin, and the pieces have every appearance of being genuine. Real counterfeits—that is, coins wholly spurious because made of base metal—are almost invariably below weight. An exception to this, however, exists in a $5 piece which is of the exact standard weight of 129 grains. It is composed of an alloy of gold and silver, and is worth from $2.70 to $3.40. Its appearance and tone are excellent, but it is thicker than the genuine coin, and hence may be detected by the gauge.

833.



A silver piece passes current so long as the imprint is not badly defaced or weight greatly reduced. A hole through the coin, however, condemns it. The counterfeiter of silver coins either makes a mould in plaster from the real coin and casts from it, or he stamps his imitation in dies. As this last process is the same as that in use in the mints, the counterfeits thus produced are more difficult to detect, because, besides being more accurately finished, the compression which the alloy receives brings it nearer to the standard weight. A large number of counterfeit silver coins are made chiefly of type metal. A very dangerous half dollar is composed of silver, copper, and zinc, and is worth about 17 cents. It is from 7 to 10 grains too light. Spurious half dollars have appeared which constantly deceive bank tellers and other experts because they are of full weight. They are made of a compound similar to German silver, and are so well plated with genuine silver that the acid does not affect them. They are, however, too thick, and the gauge, as usual where the balance fails, shows the fact. Counterfeits of the quarter dollar, though very plenty, are less dangerous than those of larger pieces. They are composed of antimony, tin, and lead, and are both too light and too thick, although they have a good ring. A peculiar composition has been employed, to which powdered glass is added to give a clear sound; but this is but a clumsy expedient, as the coin is far below proper weight, a fact easily appreciable by mere handling.

An ingenious mechanical device for detecting counterfeit coin has been invented by Mr. P. Doherty, and has been adopted in various Government offices. It consists of a balance-lever working on a knife-edged steel pivot similar to a scale-beam. The operating arm of the lever is provided with gauges and adjusting stops, formed and placed in such a manner that by a single movement or application of the coin the three essential tests of weight, diameter, and thickness are made instantly. The gauge has the form of an open slot made just large enough to admit good coin. The size of the coin is tested by the gauge as it enters, and when the coin touches the stop it is tested in weight by the lever. A counterfeit of the proper weight will not enter the gauge. A counterfeit that does enter will not move the lever. The form and position of the stop are of such convenience that it does double duty: holding the coin at a certain point on the lever while being weighed, and affording a remarkably quick and easy means of accurately adjusting the instrument. This adjustment is so fine that the gold test is sensitive to the fifth part of a grain.

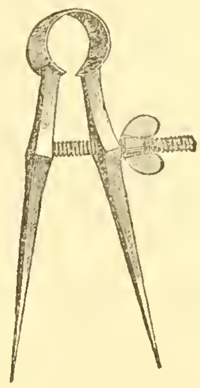
COMPASSES. An instrument consisting of a pair of arms jointed together, and therefore adjustable at any angle. It is used for purposes of measurement, and for describing arcs, circles, or, with the aid of an attachment, scrolls. Fig. 834 represents the ordinary form of compass, and Figs. 835 and 836 compass dividers. The distinction between the terms "compasses" and "dividers," which are often indifferently applied to the same instrument, rests upon the fact that the true use of compasses is to describe arcs, etc., while that of dividers is to divide lines into equal parts. Whenever it is needful to lay off numerous arcs or to measure without special accuracy being required, an ordinary compass is the proper instrument for the work, because compass legs can be separated and closed together in less time than is required for the shifting of divider legs; but to measure a length easily and precisely, spring dividers, such as are shown in Fig. 836, having fine points, are best adapted. The mode of adjusting a dividing compass to a length on a rule or other measure

consists in rotating the thumb-nut until the two dividing points are at nearly the required distance from each other; and this is effected by putting the points near the rule, but not touching it. After this the final adjustment is performed by softly placing one point upon or into one of the marks on the rule; and while this point is held in the mark with one hand, the other leg is screwed in or out

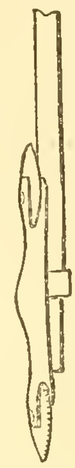
834.

835.

836.



837.



by gently working the nut until both points are seen to be in the marks. To avoid wearing the divider screw and nut to a needless extent, when the legs require shifting a great distance the two legs should be squeezed toward each other in one hand, while the other hand is used to rotate the thumb-nut during the time it is not in contact with the divider leg.

Compasses are sometimes provided with a detachable conical foot, which may be inserted in the mouth of a hole or recess in order to enable the pointed leg to describe arcs or circles around the same. An ingenious attachment by means of which compasses can be used to describe scrolls, ogees, or other irregular curves with accuracy, is represented in Fig. 837. It consists simply of a supporting holder, in one end of which is pivoted a cogged and in the other a thin-edged wheel. This holder has a sleeve or clamp by which it is attached to one of the compass legs. In operation the leg not carrying the device is held still, while the other leg is swept around, and at the same time moved inward toward the fixed point, thus forming an irregular curve. The wheel leaves the necessary mark on the metal or wood—a full line if the thin-edged roller is used, or a dotted one if the corrugated wheel is employed. In laying off patterns by this device on paper or wood, blackened manifold paper may be used for transferring the design in dark lines.

COMPOUND ENGINE. See Engines, Marine.

COMPRESSOR. See Air-Compressors.

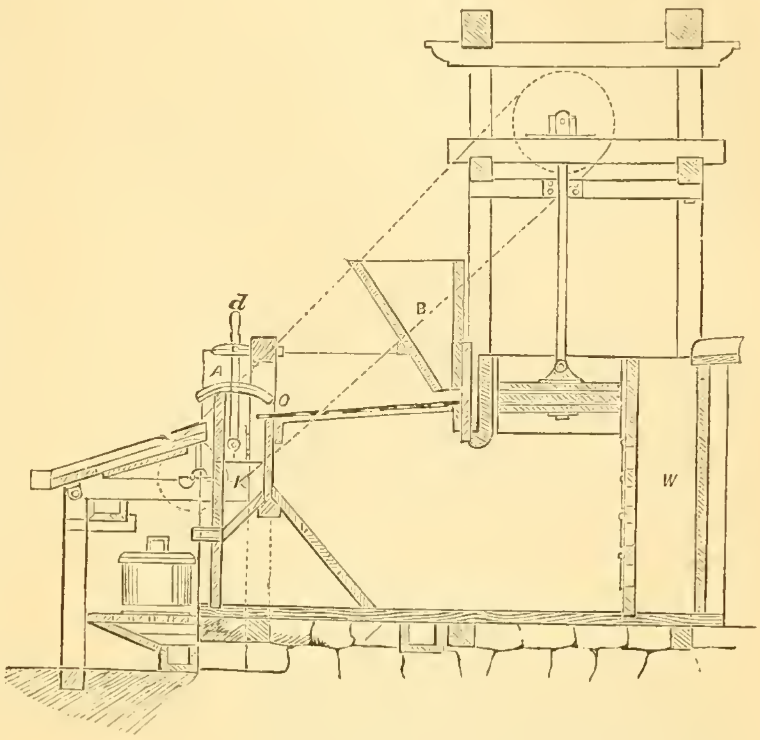
CONCENTRATING AND SEPARATING MACHINERY. Apparatus for the separation of comminuted ore according to the gravity of its particles. Concentrating machines are of two classes, according as the separation is effected through the agency of water or the air-blast.

Concentrating Machines using Water.—*Jigs.*—The idea of a jig was originally derived from the treatment by hand of ore on a sieve under water. By plunging the sieve down suddenly in the water, and allowing the particles to come again to rest upon it, a separation is effected; and if the stuff has been sized, and the operation has been sufficiently often repeated, the denser particles are found in strata under the less dense. If the mass on the sieve is then divided into horizontal layers, ore and gangue may be separated. Much attention has been directed to the construction of automatic or continuously working jigs, by which the stuff to be washed enters in a constant stream, and, after being washed and concentrated, is delivered in two separate portions without stopping or requiring manipulation. In such machines the sieves, instead of being alternately plunged into and raised out of a vessel of water, are made stationary, and the water is made to rise and fall so as to pass in a strong current through the meshes of the sieve and the layer of ore above it. This motion of the water is produced by means of plungers or pistons acting below the sieve, either vertically or horizontally, or by elastic diaphragms which are alternately pushed out and in. One of the best jigs of the continuously working class is the invention of Rittinger. It is represented in Fig. 838, and is characterized by the inclination of the grates and the lowness of the front partition, over which the poor and lighter stuff falls continuously and with very little water, while the heavier and richer portions fall through the opening or slit *o* at the base of the partition. This partition is the segment of a cylinder, and is supported upon the lever or arm *d*, so as to be movable back and forth in such a manner that the opening or slit *o* may be increased or diminished at pleasure. The heavy stuff, passing through the opening, falls into the box *K*, from which it is removed as required. The inclination of the grate in this machine is from 5° to 8°. It is fed through the hopper *B*, which plunges below the surface of the stuff accumulated on the grate. The loss of water which occurs at each stroke of the piston is replaced from a reservoir, *W*, at the back of the apparatus. According to Rittinger, experience has shown that the duty of self-acting machines of this kind is generally three times as great as that from the ordinary intermittent working apparatus.

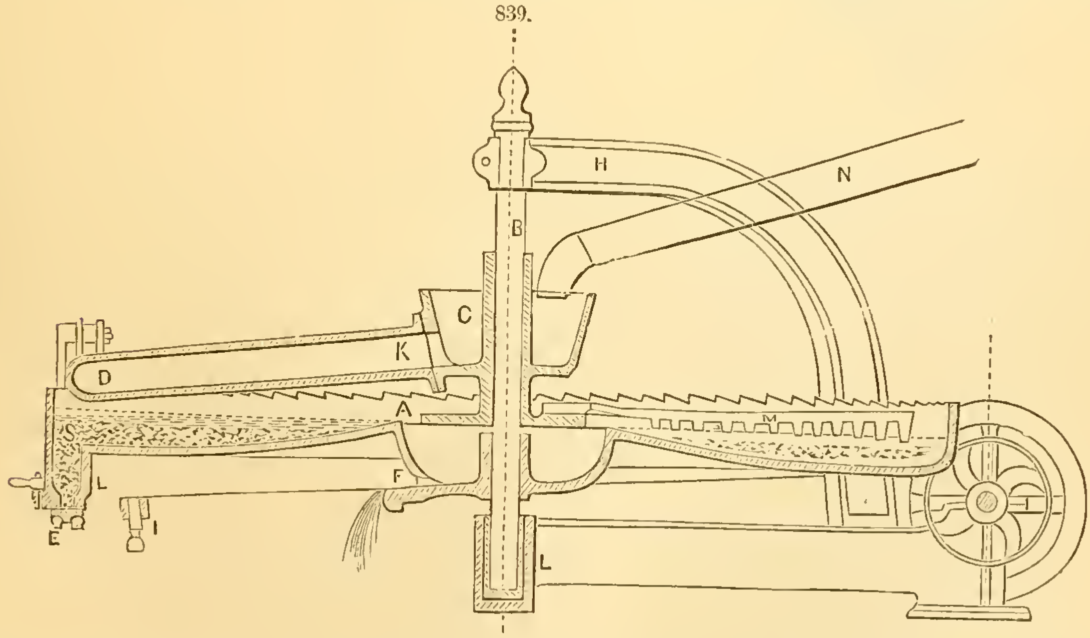
Rittinger gives the following general dimensions, derived from practical experience, as the best for the construction of jigs: 1. The opening of the feed-hopper should be of from $2\frac{1}{2}$ to 3 inches area, and about 4 inches above the sieve. 2. The length of the sieve should be at least 24, and better 30 inches, and its inclination about half an inch to the foot, in order to facilitate the discharge. 3. The height of the material resting on the sieve should not be over 4 inches at the lower end.

*Hendy's Concentrator*, Fig. 839, consists of a shallow iron pan, 5 or 6 feet in diameter, supported by a vertical shaft in the centre, and made to oscillate back and forth by means of cranks on a shaft at one side, and joined by connecting-rods to the periphery of the pan. The pan turns upon its vertical axis back and forth, for a short distance, at every revolution of the crank-shaft. The figure gives a sectional elevation of the machine. It is made wholly of iron; therefore there is no framing of timbers to be done when it is set up, and no shrinking and leaking after the machine has been allowed to stand idle for a time. A frame gives support to the central pin and the crank-shaft, and also to arched arms *H*, which rise over the pan and sustain the upper end of the vertical shaft *B*. The bottom of the pan is raised in the centre around the shaft nearly to the height of the rim, and from this it descends toward the periphery in a parabolic curve, by which the movement of the particles from the centre toward the circumference is facilitated, and their passage in the other direction obstructed. The stuff to be concentrated is delivered, together with the water, by the trough *N* to the hopper *C*, from which it is fed through the pipe *K* and distributor *D* into the pan near its outer edge. This feeding is not confined to one point, but is made to extend around all parts of the circumference, by causing the distributor *D* to rotate around the vertical shaft. This is accomplished by the movement of the pan. The upper edge of the pan is a continuous ratchet, into which two pawls connected with *D* drop during the motion of the pan from the distributor, and in the return motion give a velocity to the distributor equal to that of the pan. Continued impulses in this way keep the distributor in regular rotation around the shaft. Rake-like arms are bolted to a flange on the bottom of the hopper *C*, and are also carried around with the distributor, serving to separate

838.




839.




the compact mass of sand and sulphurets as it settles, and also breaking the scum that gathers on the surface. The accumulated sulphurets are discharged at the gate *E*. Each machine will receive and concentrate 5 tons of stuff every 24 hours.

*The Water-Column Separator.*—Various forms of apparatus have been devised to effect the separation of the grains of either coarse or fine stamp-stuff, having nearly the same volume but differing in density, by allowing them to fall through a column of water either at rest or in motion. Such machines may be regarded as modifications of the jig; a greater length of fall of the materials in water being substituted for a succession of short falls, the result of the repeated shocks or jerks

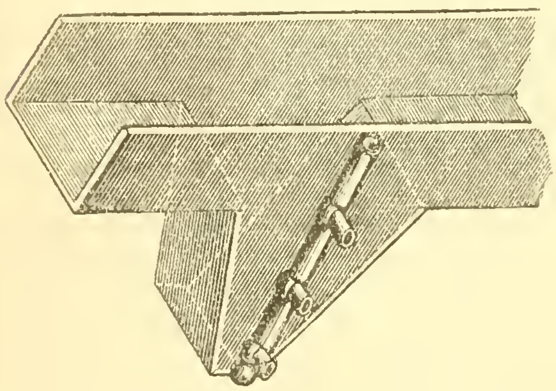
given to the sieve. Apparatus of this kind forms a connecting link between jigs and the slime separators. These machines depend for their operation upon the difference in the time required for particles to fall through a given height of column of water, which, for particles of equal size, is in the order of their specific gravities. As the time required is modified by the bulk of the particles, a careful sizing is an essential prerequisite to the success of this form of concentrating apparatus. One of the simplest forms is a stationary cylinder, designed by Messrs. Huet & Geyler of Paris. It consists of two stationary concentric cylinders, kept full of water by means of a supply-pipe, while a portion of the water escapes through the opening in the conical bottom and the excess overflows around the top. Directly below the aperture in the bottom of this cylindrical vessel a receiving tub is placed, so as to receive the water and ore that fall through. This tub is divided into compartments and rotates around a central vertical axis. The stuff to be concentrated is supplied at intervals at the top of the cylinder. In falling through the three feet of water, the particles separate according to their specific gravity, and the heaviest arrive first at the outlet and are caught in one of the compartments of the tub. As the next grade of ore reaches the outlet, the tub has turned so as to bring another compartment under the orifice, and the stuff is thus classified.

Hundt's settling-tub operates similarly, but differs in this, that the receiving tub is fixed and the water column is made to rotate.

Conical separators consist of a series of five or six cones arranged in succession one below the other. Each part consists of two cones, one inserted in the other, so as to leave an annular space in which water flows upward from a reservoir or chamber at the lower or pointed end. The stuff to be concentrated is conveyed by a launder into the upper cone, and, passing through holes, encounters the upward current. The lighter portions are at once carried upward and over the upper edge of the inner cone, and fall with the escape-water into an annular trough, by which they are conducted away to the next lower cone, while the particles of sufficient weight to resist the current fall through it, and accumulate in a small inverted cone in the chamber below, from which they are allowed to drop through a small aperture at the apex.

*Sizing and Concentration in Sluices and Rockers.*—All concentrating machines work to better advantage when the sands are of uniform size. For sizing, pointed boxes, such as that represented in Fig. 840, are simple and efficient contrivances. The box is of wood and wedge-shaped. Its length

840.



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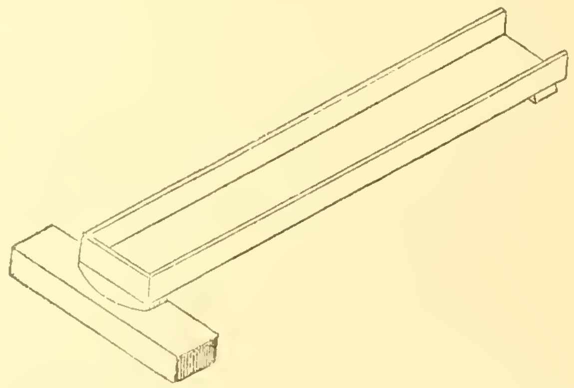


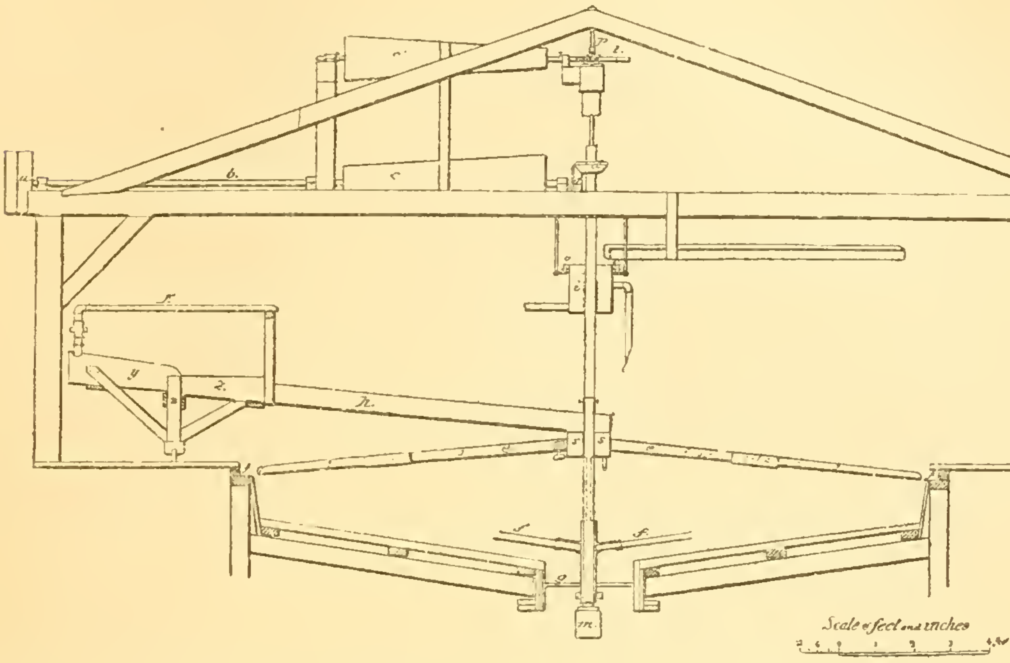
depends on the size of the grain desired for the concentrating machine. The shorter the box, the larger the size of the grain (breadth and grade of the sluices or the velocity of the sluice current being the same). The sands settling in the box are discharged by a 2-inch iron pipe communicating with the interior of the box at the bottom, reaching to the top of the water-level in the sluice, and provided on the side with 1½-inch plug-holes from 4 to 6 inches apart from centre to centre. The proportion of water to sands is regulated by opening the plug-holes at different depths below the water-level, the lowest hole naturally discharging the greater quantity of water with the sands deposited in the box. The sands afterward flow through wooden sluice-boxes of a rectangular section, provided at the lower end with a self-raising gate acting as a riffle, in which the heavier portions of the sands, consisting of sulphurets, etc., form a deposit near the head, while the lighter particles escape over the gate. For every two boxes or two sets of boxes there is one riffle-gate. When the sluice-sands are subjected to a further concentration, they are discharged into a tank by lowering the riffle-gate.

The rocker represented isometrically in Fig. 841 consists of a wooden table of 2-inch pine plank, 20 inches wide and 10 feet long, supported at both ends by wooden rockers, representing a section of a width of 20 inches and depth of about 3 inches. The table has a grade of about 1 inch to the foot, which can be increased when coarser sands are worked. The concentrated sluice-sands are introduced at the head of the rocker, and a stream of water is turned on them. The rocker is set in motion by the left hand of the workman, giving it about 60 strokes of 8 inches a minute. For coarser sands a greater number of strokes is required. The lighter sands gradually work down, while the sulphurets remain nearer the head.

*Buddles* are oblong inclined vats in which stamped ore is exposed to the action of running water, in order that the lighter portions may be washed away while the heavier are retained. The concave buddle of Paine & Stevens is shown in Fig. 842. There are generally two buddles, one for the coarser sluice-concentrates, and the other for the finer. They are of an exterior diameter of 18 to 20 feet, and interior of 2½ feet. The vertical shaft is supported by the wooden block *m*, carrying the journal-box. Attached to the shafts are: 1, the self-raising riffle-pulley *g*, which is raised by means of a

rod $p$, receiving its upward or downward motion from the endless screw $b$ and pinion-wheel; 2, the arms $f\ f$, carrying the brusher; and 3, the sand-distributing troughs $e\ e$. The clear-water box $i$ is suspended by the wheels $v\ v$ on an annular flat ring. It is supplied by the stationary wooden box $r$, and discharges the water by means of the iron pipe $k$ into the sieve-boxes $y$ and $z$. The box $s\ s$ is

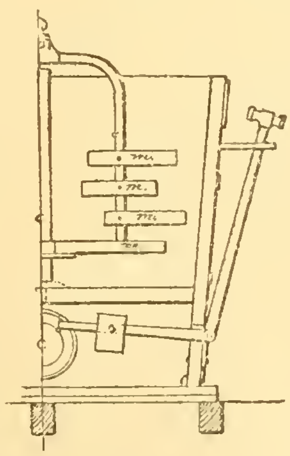
842.



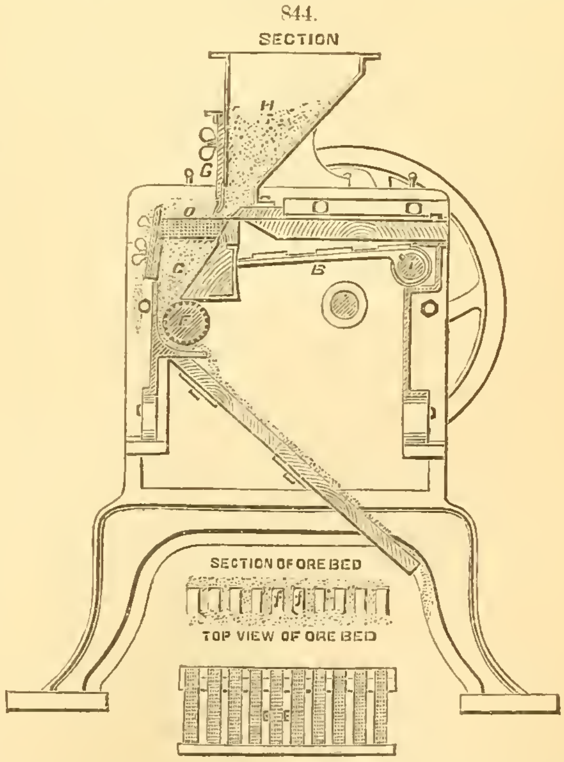
fed by the trough $h$ from the mixing-trough $y$ and sieve-box $z$. The vertical shaft receives its motion by the pulley $a$ and bevel-gearing $d\ d$.

The tossing or final cleaning of sulphurets from auriferous sands is usually performed on the buddle-headings if they are intended to be treated by the chlorination process. This is done in a *tossing tub* of the following construction, Fig. 843. Through the axis of the tub, which is conical in form, passes the hollow cast-iron cone $c$. A shaft passing through this cone and resting on a journal underneath carries a yoke to which the horizontal stirrers of flat iron are riveted. Revolution is communicated to the shaft by bevel-gearing. The hammers are set in motion by the pins attached to the vertical bevel-gear. When ready for tossing, the tub is filled to nearly half its height with water, the stirrers are set in motion, making 48 revolutions a minute, and the ore is shoveled in near the periphery of the tub When nearly full, the yoke is lifted out by means of a rope and pulley overhead, and the sands are allowed to settle while the hammers are set in motion, making 96 strokes each a minute to facilitate the rapid settling of the sulphurets and sands. When the sands have settled, the water is drawn off by an iron siphon, and the skimmings are removed to a depth of 2 inches and thrown out as waste. The upper half of the sands remaining are retossed, and the resulting sands above the sulphurets washed again in the buddle during doubling. The lower half, of about 5 to 6 inches, consisting of sulphurets sufficiently concentrated, is delivered at the chlorination works to be further treated for gold. (See CHLORINATING MACHINERY.)

843.



844.




CONCENTRATING MACHINES USING AIR-BLAST.—*Krom's Dry Ore Concentrator.*—A sectional view of Krom's dry concentrator is given in Fig. 844. The machine is composed essentially of the following parts: a receiver $H$, to hold the crushed ore; an ore-bed $O$, on which the ore is submitted to the action of the air; the two gates $G$, one to regulate the flow of ore from the receiver $H$, the other to determine the depth of ore on the ore-bed; a passage $C$, in which the concentrated ore descends, and roller $F$, to effect and regulate the dis-

charge of the same; a fan $B$, to give the puffs of air; a trip-wheel lever and spring, to operate the fan; and a ratchet-wheel and pawl, to impart revolution to the roller $F$.

The mode of operating the machine is as follows: Ore is placed in the receiver $H$, and the driving-pulley set in motion. The trip-wheel, fixed on the opposite end of the pulley-shaft, works by its cam-shaped teeth against the lever; and by the alternate action of this wheel, forcing the lever in one direction, and of the spring, which at once and suddenly carries it back again, the fan $B$ is made to swing on the shaft $I$, sending at each upward movement a quick and sharp puff of air through the ore-bed, and lifting slightly the ore lying on it. As there are six projections upon the trip-wheel, it follows that the moderate speed of 70 to 80 revolutions of this per minute will give 420 to 480 upward movements of the fan in the same time, and consequently a corresponding number of puffs of air to agitate the ore; this rate is sufficient to secure steady motion of the heavy balance-pulley, and yet not so fast as to produce any unpleasant jar or noise. The ore-bed is composed of wire-gauze tubes, placed at distances from each other of $\frac{3}{16}$, $\frac{1}{4}$, $\frac{3}{8}$, and $\frac{1}{2}$ of an inch, according to the grade of ore to be concentrated—the finer requiring that the tubes be set nearer together, while the coarser allow of their being farther apart. The ore-bed, situated in front of the fan, as plainly shown in the sectional view, is formed by these tubes, their ends next to the fan being open; and the air from the bellows, entering these, escapes through the top and sides of the tubes, agitating the ore that lies on them, and also that between them near the surface. The ore between the tubes rests on that immediately underneath, in the passage $C$, and sinks as fast as the roller $F$, at the bottom, effects its discharge. The tubes being open on the lower side, any fine ore passing through the meshes of wire gauze simply descends with the main body $C$, thus preventing any liability of the tubes to filling up. In discharging the concentrated ore $C$, the roller $R$ is operated (as mentioned above) by means of the ratchet-wheel and pawl, and, the latter being carried by a crank on the trip-wheel, it follows that its speed is governed by the speed of this wheel, which also gives motion to the fan $B$; by this connection the fan, which effects the concentration, and the roller, which discharges the concentrated ore, are made to act in concert with each other.

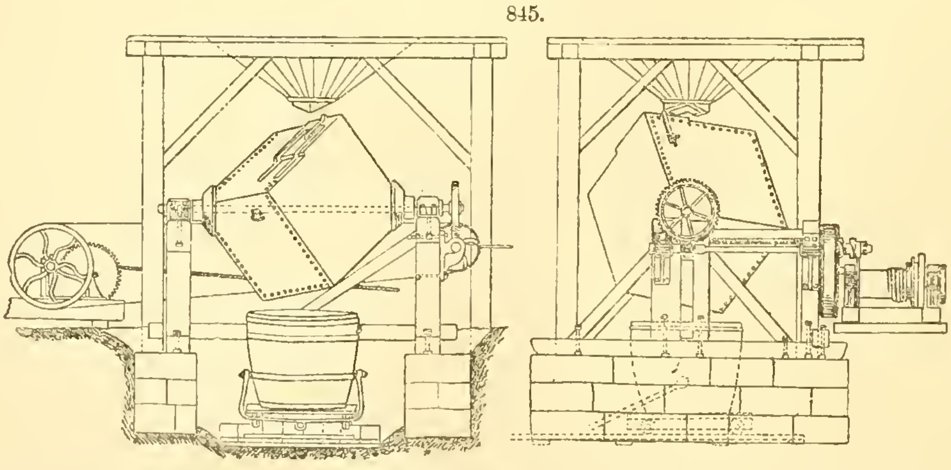
CONCRETES AND CEMENTS. The term concrete is applied to a mortar of finely-pulverized quicklime, sand, and gravel, which materials are first mixed dry, made to the consistence of mortar with water, and thoroughly worked. The most approved proportions are those in which the lime and sand are in the proper proportions to form a good mortar, and the gravel is twice the bulk of the sand. The bulk of a mass of concrete when first made is found to be about one-fifth less than the total bulk of the dry materials; but as the lime slakes, the mass expands about three-eighths of an inch in height for every foot of the mass in depth. The use of concrete is now mostly restricted to the forming of solid beds in bad soils for foundations, for blocks of artificial stone, and for walls of edifices.

"Béton" is the term applied by French engineers to any mixture of hydraulic mortar with fragments of brick, stone, or gravel. It is generally used in the same sense. The smallest amount of mortar that can be used will be that which will be just equal in volume to the void spaces in any given bulk of the broken stone or gravel. The best and most economical béton is made of a mixture of broken stone or brick in fragments not larger than a hen's egg, and of coarse and fine gravel mixed in suitable proportions. The mortar is first prepared and then incorporated with the finer gravel; the resulting mixture is spread out into a cake about 6 inches thick, over which the coarse gravel and broken stones are uniformly strewed and pressed down, the whole mass being finally brought to a homogeneous state with the hoe and shovel.

The terms "béton" and "concrete," while not originally synonymous, have become almost strictly so by usage. The matrix of béton possesses hydraulic energy, while that of concrete does not; and herein is the accurate distinction.

For mixing concrete, a boiler-iron box, placed diagonally on a shaft and rotated, is commonly employed, as shown in Fig. 845. The ingredients are thrown into the hopper above, and thence pass

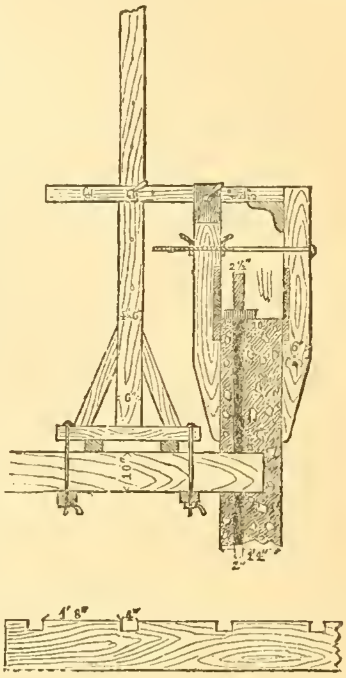
845.



through the open door into the box. The latter is then revolved, and when the materials are thoroughly compounded it is emptied into a suitable receptacle placed beneath. Wheelbarrows are generally used for conveying the concrete from where it is mixed to wherever it is needed; but when large quantities are prepared by machinery which is not portable, a sling-cart may be advantageously used. The box should be of stout planks, and about $5\frac{1}{2}$ feet long, $3\frac{1}{2}$ feet wide, and 9 to 10 inches deep, and so arranged that it can be readily slung up underneath the cart by means of a windlass.

For erecting concrete walls, the apparatus devised by Mr. E. E. Clarke, Fig. 846, is often employed. It consists of a wooden clamp, the vertical parallel arms of which can be readily adjusted by means of traverse screws to any thickness of wall. These arms support the planking which determines the thickness of the structure, and are attached—one fixed and the other movable—to a horizontal brace. When in use the entire apparatus is kept in position by securing this brace to some fixed point of support. The illustration represents the apparatus in position for laying a hollow concrete wall, not intended to be furred inside. The hollow is secured by means of a movable plank, called a core, a trifle thinner on the lower than on the upper edge, so that it can be moved after the concrete is rammed around it. The ties between the inner and outer walls may be common bricks, and these are placed under the core, in each of its positions, as the building progresses. The core is notched on the lower edge, so as to fit down upon the ties flush with their lower beds.

846.



A more simple apparatus for making concrete walls consists merely of a boxing of planks kept in place by upright posts on the exterior at suitable distances apart, say 4 or 5 feet. The lower ends of the posts are mortised and keyed into horizontal cross-pieces called futtocks, which reach entirely through the wall, and are withdrawn and the holes filled up after the box is filled with concrete and a new course is to be commenced. The upper ends of the posts may be kept in position by similar cross-pieces, but the more common practice is to confine them by lashings of rope or cord, tightened or loosened at pleasure by a stick used as a lever.

Fence or railing posts, of the minimum size consistent with the requisite degree of strength, may be firmly set and retained permanently in their upright position by inserting them in concrete foundations. The mortar for this purpose need not be very rich in cement, and in quantity might barely exceed the volume of voids in the coarse material.

Concrete floors are frequently used in fire-proof buildings. The concrete is in some cases packed in between the iron beams, and in others is used in the form of slabs or plates.

The quick-setting varieties of hydraulic cement are quite extensively used for the manufacture of drain and sewer pipes. The mortar, composed of 2 to 2½ measures of clean coarse sand to 1 measure of the cement powder, mixed with a small quantity of water, is moulded by special machinery into pipe in sections of suitable length. These sections, when joined together with cement-mortar, form a continuous water-tight tube.

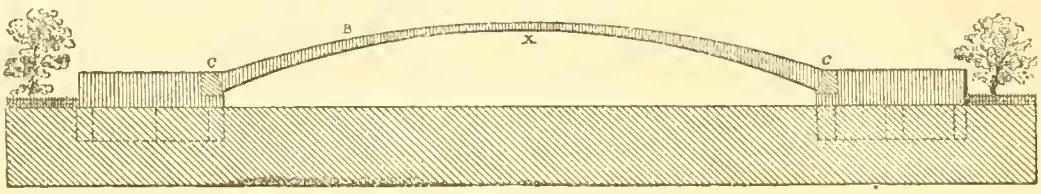
*Béton blocks for building purposes* are of great value in regions where stone of large size or skilled labor to cut the same is scarce. Such blocks have been employed in the construction of the new piers and docks of New York. The materials employed were: 1. Portland cement of two brands, tested to withstand a tensile strain per square inch of not less than 200 lbs. in the first and 250 lbs. in the second case. 2. Seashore sand, sharp, clean, and rather coarse than fine, used without any preparation. 3. Broken stone (trap rock), not too large to pass through a ring 2 inches in diameter, and not less than a quarter of an inch in smallest dimensions. The formulas were: 1 volume of cement, 2 of sand, and 5 of stone; and 1 of cement, 2½ of sand, and 5½ of stone; the unit of measure being a cement barrel. In mixing, 2½ barrels of sand were spread on the mortar-bed to the depth of 3 inches. Cement was then evenly distributed over the sand, and both materials were mixed with hoes; 18 gallons of water was then added, which produced a stiff but plastic mortar. In the mean time 5 or 5½ barrels of stone were spread to a depth of 6 inches on a turning platform, and on this the mortar was evenly shoveled. Thorough mixing with shovels followed, and finally the béton was carried to the moulds. The mass was then evenly and partially rammed, a 36 lb. rammer, falling 6 or 8 inches by its own weight, giving good results. The moulds, ranging in capacity from 1 to about 23½ cubic yards, were made of 2-inch spruce plank, tongued, grooved, and dressed to 1¾ inch thickness by 4½ inches in width, nailed with 30-penny nails to pine pieces 5 × 6 inches, placed 28 inches apart, and capped by a pine plate 5 × 8 inches, into which the uprights were mortised. When the uprights were arranged to enter into mortises in the platform, allowance was made for a tenon of the width of the upright, 1¾ inch thick and 2¼ inches long. Tenons, however, were successfully dispensed with, by screwing strips to the platform with ⅝-inch lag-screws. The ends of the moulds were dadoed into the side-pieces and secured firmly with a ⅝-inch iron rod, ending with a crank-handle nut to draw the sides closely to the end pieces.

The béton made as above, when a year old, weighed per average of 10 blocks 156 lbs. per cubic foot; or the weight of a cubic yard might safely be taken as 4,200 lbs. When immersed in water as soon as it could be handled safely, at 45 days old it yielded to a crushing force of 420 lbs. to the square inch, or say 30 tons to the square foot; and under the same conditions, at a year old, it yielded to a crushing force of 1,520 lbs. to the square inch, or say 110 tons to the square foot. When dried in air it yielded to a crushing force of 1,620 lbs. per square inch, or say 116 tons to the square foot. Béton made by the same formula, wherein "lime of Teil" was substituted for Portland cement, after 45 days' immersion yielded to a pressure of 256 lbs. per square inch, or say 18½ tons per square foot; after a year's immersion it yielded to a pressure of 1,079 lbs. per square inch, say 79 tons per square foot; and at a year old in air it yielded to a pressure of 1,087 lbs. per square inch, or say about 78 tons per square foot. These blocks could not be safely handled unless at least a month old, and then the corners were very liable to injury; while blocks made with Portland cement, weighing nearly 53½ tons, when only 8 days old, were easily lifted by the derrick. The cost of

materials ranged from about $7.88 to $8.88 per cubic yard; and of manual labor, including carpenters repairing moulds, etc., about $5 per cubic yard.

*Béton Coignet*, so called from its inventor, is composed of clean river-sand 4 or 5 parts by volume, hydraulic or common lime 1 part, hydraulic or artificial Portland cement one-quarter to three-quarters part, and water enough to moisten the materials. The compound is put into the moulds in successive layers from 1 to 3 inches in thickness, and is packed by hand. One of the most important structures of this material is the monolithic arch of St. Denis, France, represented in Fig. 847. This was erected for the purpose of testing the béton. The span is 196 feet 10 inches; elevation of

847.




arch, 19 feet 8 inches; cross-section at $X$, 3 feet 11 inches by 3 feet 3 inches; at $C$, 6 feet 6 inches by 6 feet 6 inches. The composition of the concrete in the arch consists of river-sand 4 parts, hydraulic lime 1 part, and Portland cement one-half part. The French aqueduct of La Vanne is built from blocks of béton Coignet.

Ransome's artificial stone consists of clean river-sand, the grains of which are cemented by silicate of lime. This stone is extremely hard, and some specimens have offered as great a resistance to rupture by compression as the best sandstone and marbles.

For concrete foundations, see FOUNDATIONS and BREAKWATERS.

*Roman Cement.*—The materials employed in the manufacture of this cement are the nodules, of an ovoidal or globular form, which are found in the London clay, and known by the name of *Septaria.* They are calcined in perpetual lime-kilns with coal, in which a very moderate and well-regulated heat is carefully preserved. After calcination the stones are ground under heavy edge-stones to a very fine powder, which is sifted, and then packed in casks for sale. These nodules are found in many localities in this country.

Roman cement is one of the most powerful hydraulic mortars, and is exceedingly valuable, not only on account of the rapidity with which it hardens (and this is effected in a very few minutes), but because when hardened in considerable masses it is not liable to crack.

All artificial or natural hydraulic limestones are soluble (before as well as after calcination) in muriatic acid, with the separation of silica, except when sand or some similar substance has been added to them.

The hydraulic limestones, when they do not contain a sufficient quantity of lime to be capable of slaking with water, must be very finely pulverized; it is only by this high state of division that a proper action can ensue. A thorough penetration of the silicious portion by the lime is never entirely effected, but a certain proportion remains inclosed and removed from the sphere of action.

MORTAR.—A mixture of *slaked lime* in the state of paste with *sand* possesses the property, when spread in thin layers between bricks, of gradually hardening to the consistence of limestone, and thus cementing the bricks together. In order to understand the principles upon which mortar is mixed, it is necessary to become acquainted with certain facts which here exert the greatest influence.

*Conditions of Hardening.*—Simple lime, in the state of paste, likewise hardens, but only to form a loose mass, of too slight consistence to bind the parts of a wall or building firmly together. It is only when the layer of lime forms a very thin stratum, as between two polished stones, that a firm and solid cement is produced. The lime must be prevented from forming masses of any considerable thickness, as these always possess a very slight degree of cohesion. The lime attaches itself firmly only to the surface of the building-stones, which differ from it in character, and this surface should be extended, as it were, by mixing a *granular powder* with the lime. This leads directly to the object and use of sand in the mortar, which is only intended to bring about more intimate contact between the surfaces of the stones and the lime. The shape of the bricks and hewn stones is so irregular that crevices of a line at least, and in hewn stones often of an inch in width, are left between them when laid one upon another. Lime alone placed between the stones would, consequently, be in layers of a line to an inch in thickness, and in such masses would never bind. If, however, a sandy powder of any kind of stone is mixed with it, the mass of lime is thus divided into a great number of thin layers, or, as it were, fills up the interstices between the sand, and, finding everywhere points of attachment, binds the grains of sand together, and extends this binding action to the stones themselves.

It is further known that even the best mortar, when quickly dried, as for instance on the stove, does not harden, but remains friable and porous. Although, therefore, mortar placed under water remains porous and will not bind, yet the action of moisture is essential to make it harden in the air. Lastly, the free access of air is also absolutely necessary to the setting of mortar.

*Proportions of Mixture.*—When these facts are borne in mind, the rules to be observed in mixing mortar will be obvious. Although many kinds of stone in the form of coarse sand are applicable for making mortar, as limestone, for instance, yet quartz-sand is always most easily obtained. The grain of the sand, however, is a matter of some importance. Very fine sand renders the mortar too dense, and impedes the free access of air; sand in grains of the size of hay-seed, particularly if it is angular or sharp, is very good; the interstices become too large to be entirely filled with lime if very coarse sand is employed. It is then advantageous, particularly when irregularly shaped build-

ing-stones are used, to mix two kinds of sand together, coarse and fine. Fine sand can only be mixed with the lime when the mortar is intended for a thin coating upon the surface of walls, etc. The more irregular the sand is, the better. The proper proportion of sand and lime is a most important point in preparing mortar; and the good quality and solidity of the mortar are more influenced by it than by anything else. Errors committed in the mixing can never be subsequently corrected.

As a general rule, the lime should be sufficiently fine to cement all the grains of sand together, but should form at the same time the thinnest possible stratum between them. The surfaces of the grains of sand, or the interstices between them, should therefore be only just covered with the lime in a half-liquid state, and no more. The rule might be laid down in the following terms: Let as much lime be mixed with the sand as it will take up without having its volume increased. Practically, about 3 to 4 cubic feet of sand (or six times the weight) are added to 1 cubic foot of half-liquid lime, provided the lime be fat, or very fat; poor lime, which may be viewed as already containing a certain portion of sand, will not bear the addition of more than $2\frac{1}{2}$ cubic feet of sand to 1 cubic foot of lime. The sand should be pure; i. e., it should not contain too much iron or clay, and, least of all, bog-earth or vegetable matter.

*Hardening or Setting—Time required.*—Although mortar sets sufficiently in a few days, or weeks, to enable a wall to withstand pressure and the like, yet the hardening proceeds so slowly and gradually that it only attains its maximum (in which case a wall appears as if constructed of one piece of stone) after years, or even centuries. The apparent superiority of mortar in olden times over that in the present is solely attributable to the longer time which has been allowed it to harden and set, as no essential difference can be traced in the mixture of the ingredients. Although we see, on the one hand, that old buildings can only be destroyed with the aid of powder, yet it must not be forgotten, on the other, that in some buildings the direct converse is observed, and that the durable portions only have been enabled to withstand the ravages of time, while the weaker and less durable parts have long since disappeared. In the same manner, it is probable that some buildings erected in our own age will stand forward to posterity as patterns of solid architecture, just as those of the middle ages and of the ages of Greece and Rome appear to us at present.

STRENGTH OF CEMENTS.—Table I.* shows the tractile strength per square inch of cement mortar 42 days old, kept in open air:

TABLE I.

| CEMENT. | PROPORTION OF SAND FOR 1 OF CEMENT. | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
| | RESISTANCE PER SQUARE INCH, IN POUNDS. | | | | | | | | | | |
| Portland cement.... | $284\frac{1}{2}$ | $284\frac{1}{2}$ | $199\frac{1}{5}$ | $16[illegible]\frac{1}{2}$ | $142\frac{1}{4}$ | 128 | $116\frac{3}{8}$ | $106\frac{3}{8}$ | $99\frac{1}{2}$ | $92\frac{1}{2}$ | $95\frac{1}{8}$ |
| Roman cement...... | $142\frac{1}{4}$ | $142\frac{1}{4}$ | $113\frac{3}{4}$ | $9[illegible]\frac{1}{2}$ | $7[illegible]\frac{3}{8}$ | 67 | 57 | $42\frac{3}{8}$ | $35\frac{1}{2}$ | $25\frac{6}{10}$ | 0 |

The following conclusions were drawn from an extended series of experiments, undertaken to ascertain the adhesion of mortar to the solid materials used in constructions:

1. That particles of unground cement exceeding one-eightieth of an inch in diameter may be allowed in cement paste without sand to the extent of 50 per cent. of the whole, without detriment to its adhesive or cohesive properties, while a corresponding proportion of sand injures the strength of the mortars in these respects about 40 per cent. 2. That when these unground particles exist in the cement paste to the extent of 66 per cent. of the whole, the adhesive strength is diminished about 28 per cent. For a corresponding proportion of sand the diminution is 68 per cent. 3. The addition of these siftings exercises a less injurious effect upon the cohesive than upon the adhesive property of cement. The converse is true when sand, instead of siftings, is used. 4. In all the mixtures with siftings, even when the latter amounted to 66 per cent. of the whole, the cohesive strength of the mortars exceeded its adhesion to the bricks. The same results appear to exist when the siftings are replaced by sand, until the volume of the latter exceeds 20 per cent. of the whole, after which the adhesion exceeds the cohesion. 5. At the age of 320 days (and perhaps considerably within that period), the cohesive strength of pure cement mortar exceeds that of Croton front bricks. The converse is true when the mortar contains 50 per cent. or more of sand. 6. When cement is to be used without sand, as may be the case when grouting is resorted to, or when old walls are to be repaired by injections of thin paste, there is no advantage in having it ground to an impalpable powder. It has been determined that most American cements will sustain without any great loss of strength a proportion of lime paste equal to that of the cement paste, while a quantity equal to one-half to three-fourths the volume of cement paste may be safely added to any Rosendale cement without producing any essential deterioration of the quality of the mortar. By the use of lime is secured the double advantage of slow setting and economy.

Table II. shows the adhesion to Croton front bricks and fine-cut granite of mortars containing different proportions of sand. The mortar was of the consistence ordinarily used for brick-masonry, and the bricks were used wet, and were pressed well together by hand. They were wetted with fresh water every alternate day for 29 days, the age of the mortar when tested. Each result is the average of five trials. The right-hand column shows the ratio of the adhesive strength of the several mortars, assuming that of pure cement to be 1.

* Tables I., II., III., IV., and V., with accompanying notes, are taken by permission from "Limes, Hydraulic Cements, and Mortars," by General Q. A. Gillmore, U. S. A. D. Van Nostrand, publisher, New York.

TABLE II.

| NO. OF MORTAR. | COMPOSITION OF THE MORTAR. | Materials Cemented. | Weight in Pounds required to tear the Bricks apart. | Adhesion per Square Inch, in Pounds. | Ratio of Adhesion. |
|---|---|---|---|---|---|
| 1 | Pure cement paste........................ | Croton bricks........ | 421 | 30.8 | 1.00 |
| 2 | 1 volume cement powder, 1 volume sand .... | " " ........ | 215 | 15.7 | 0.51 |
| 3 | 1 " " " 2 " .... | " " ........ | 169 | 12.3 | 0.40 |
| 4 | 1 " " " 3 " .... | " " ........ | 94 | 6.8 | 0.22 |
| 5 | 1 " " " 4 " .... | " " ........ | 71 | 5.2 | 0.17 |
| 6 | 1 " " " 5 " .... | " " ........ | 59 | 4.3 | 0.14 |
| 7 | 1 " " " 6 " .... | " " ........ | 45 | 3.3 | 0.11 |
| 8 | Pure cement paste........................ | Fine-cut granite..... | 440⅜ | 27.5 | 1.00 |
| 9 | 1 volume cement powder, 1 volume sand .... | " " ..... | 332⅜ | 20.8 | 0.76 |
| 10 | 1 " " " 2 " .... | " " ..... | 201 | 12.0 | 0.46 |
| 11 | 1 " " " 3 " .... | " " ..... | 146⅜ | 9.2 | 0.33 |
| 12 | 1 " " " 4 " .... | " " ..... | 127 | 7.9 | 0.29 |

Table III. shows the ultimate strength of rectangular parallelopipeds (2″ × 2″ × 8″) of cement paste and mixtures of cement and lime paste without sand, formed in vertical moulds under a pressure of 32 lbs. per superficial inch, and broken when 95 days old, on supports 4 inches apart, by a force applied at the middle. The mortars were kept in sea-water from the time they were one day old.

TABLE III.

| NO. OF MORTAR. | COMPOSITION OF THE CEMENT. | Penetration of the Point in Inches. | | Weight in Pounds supported before Breaking. | Average Breaking Weight of each kind of Mortar. |
|---|---|---|---|---|---|
| | | 1 Impact. | 2 Impacts. | | |
| 1 | Pure cement paste (average of two trials)........ | .114 | .195 | 994 | 1,002½ lbs. |
| 2 | " " " " ....... | .112 | .163 | 957 | |
| 3 | " " " " ........ | .117 | .192 | 1,025 | |
| 4 | " " " " ........ | .107 | .187 | 1,034 | |
| 5 | Cement paste, 1 volume; lime paste, ¼ volume.... | .155 | .250 | 1,000 | 979¾ " |
| 6 | " " " " .... | .160 | .250 | 996 | |
| 7 | " " " " .... | .147 | .245 | 992 | |
| 8 | " " " " .... | .... | .... | 931 | |
| 9 | " " " ½ volume.... | .175 | .250 | 863 | 816 " |
| 10 | " " " " .... | .155 | .265 | 847 | |
| 11 | " " " " .... | .150 | .200 | 785 | |
| 12 | " " " " .... | .150 | .195 | 769 | |
| 13 | " " " ¾ volume.... | .120 | .200 | 597 | 565½ " |
| 14 | " " " " .... | .200 | .200 | 570 | |
| 15 | " " " " .... | .180 | .220 | 513 | |
| 16 | " " " " .... | .... | .... | 582 | |
| 17 | " " " 1 volume.... | .187 | .395 | 597 | 569¾ " |
| 18 | " " " " .... | .180 | .295 | 574 | |
| 19 | " " " " .... | .207 | .325 | 558 | |
| 20 | " " " " ... | .210 | .330 | 550 | |
| 21 | " ¾ volume " 1 volume.... | .180 | .300 | 365 | 364½ " |
| 22 | " " " " .... | .200 | .320 | 363 | |
| 23 | " " " " .... | .180 | .293 | 355 | |
| 24 | " " " " .... | .180 | .290 | 375 | |
| 25 | " ½ volume " " .... | .200 | .300 | 339 | 305¼ " |
| 26 | " " " " .... | .220 | .340 | 316 | |
| 27 | " " " " .... | .230 | .260 | 286 | |
| 28 | " " " " .... | .270 | .380 | 280 | |

Other mortars of light-colored Rosendale cements and lime, mixed, formed into blocks of the same size, preserved and broken in precisely the same manner as the foregoing, gave the following results when 95 days old. The average of four trials is given in each case.

TABLE IV.

| NO. OF MORTAR. | COMPOSITION OF THE MORTAR. | Breaking Weight, in Pounds. |
|---|---|---|
| 1 | Cement paste, 1 volume; lime paste, $\frac{1}{9}$ volume.............................. | 728 |
| 2 | " 1 " " ¼ " .............................. | 723¼ |
| 3 | " 1 " " ⅔ " .............................. | 732 |
| 4 | " 1 " " 1 " .............................. | 608 |

Water-glass, while it renders common mortar hydraulic, injures its strength and its adhesive properties, and is greatly inferior to cement as a hydraulic agent in both efficiency and economy, irrespective of the degree of energy required.

Table V. shows the strength of mortars of various cements made into prisms 2″ × 2″ × 8″ in vertical moulds, under a pressure of 32 lbs. per square inch, and broken on supports four inches apart, by a pressure midway between the supports. The prisms were kept in sea-water after the first 24 hours, and were 320 days old when broken. The breaking weights given are averaged from many trials. The cement was measured in powder.

TABLE V.

| No. of Mortars. | Kind of Cement Used. | Breaking Weights of Mortars Composed of: Pure Cement. | Cement, vol. 1, Sand, vol. 1. | Cement, vol. 1, Sand, vol. 2. |
|---|---|---|---|---|
| | | Pounds. | Pounds. | Pounds. |
| 1 | English Portland (artificial) | 1,536 | 1,260 | 950 |
| 2 | Cumberland, Maryland | 951 | 920 | 558 |
| 3 | Newark and Rosendale | 841 | 560 | 500 |
| 4 | Delafield and Baxter (Rosendale) | 836 | 692 | 532 |
| 5 | "Hoffman" Rosendale | 849 | 607 | .... |
| 6 | "Lawrence" Rosendale | 777 | .... | .... |
| 7 | Round Top, Maryland | .... | 600 | .... |
| 8 | Utica, Illinois | 732 | 756 | 562 |
| 9 | Shepherdstown, Virginia | 747 | 618 | 450 |
| 10 | Akron, New York | 764 | 651 | 603 |
| 11 | Kingston and Rosendale | 720 | 556 | 500 |
| 12 | Sandusky, Ohio | 554 | 464 | .... |
| 13 | James River, Virginia | .... | 623 | 638 |
| 14 | *Roman cement, Scotland | 553 | .... | 380 |
| | The following were broken when one year old: | | | |
| 15 | Lawrenceville Manufacturing Company (Rosendale) | .... | 910 | .... |
| 16 | Sandusky, Ohio | 802 | .... | .... |
| 17 | Kensington, Connecticut | 954 | 709 | 506 |
| 18 | Lawrence Cement Company (Rosendale), "Hoffman" Brand | 875 | 911 | .... |
| 19 | Round Top, Maryland | .... | 840 | .... |

*Crushing and Tensile Strength of the Hydraulic and other Cements at the Philadelphia Exhibition.*

| | Name of Exhibitor and Place of Manufacture. | Crushing Strength: Average Strength per Square Inch. | Crushing Strength: No. of Trials. | Tensile Strength: Average Strength per Square Inch. | Tensile Strength: No. of Trials. |
|---|---|---|---|---|---|
| | PORTLAND CEMENT. | Pounds. | | Pounds. | |
| 1 | Toepffer, Grawitz & Co., Stettin, Germany | 1,439 | 12 | 216 | 3 |
| 2 | Hollick & Co., London, England | 1,330 | 10 | 216 | 3 |
| 3 | Wouldham Cement Co., London, England | 1,140 | 12 | 199 | 3 |
| 4 | Saylor's Portland Cement, by Coplay Cement Co., Coplay, near Allentown, Pa., U. S. | 1,078 | 8 | 184 | 2 |
| 5 | Wampum Cement and Lime Co., Newcastle, Lawrence Co., Pa., United States | 968 | 12 | 168 | 3 |
| 6 | Pavin de Lafarge, Teil, canton of Viviers, department of Ardèche, France | 931 | 12 | 158 | 3 |
| 7 | A. H. Lavers, London, England | 926 | 6 | 192 | 2 |
| 8 | Francis & Co., London, England | 907 | 14 | 163 | 3 |
| 9 | William McKay, Ottawa, Canada | 882 | 10 | 141 | 3 |
| 10 | Borst & Roggencamp, Delfzyl, Netherlands | 826 | 12 | 132 | 3 |
| 11 | Longuety & Co., Boulogne-sur-Mer, France | 764 | 12 | 108 | 3 |
| 12 | Riga Cement Co., by C. X. Schmidt, Riga, Russia | 693 | 5 | 134 | 2 |
| 13 | Scanian Cement Co., Lomma, near Malmo, Sweden | 606 | 14 | 112 | 3 |
| 14 | Bruno Hoffmark, Port Kund, Esthland, Russia | 580 | 6 | 154 | 2 |
| | ROMAN AND OTHER CEMENTS. | | | | |
| 15 | Coplay Hydraulic Cement, by Coplay Cement Co., Coplay, near Allentown, Pa., U. S. | 292 | 8 | 38 | 2 |
| 16 | Charles Tremain, Manlius, N. Y., United States | 276 | 12 | 47 | 3 |
| 17 | Allen Cement Co., Siegfried's Bridge, Pa., United States | 276 | 12 | 43 | 3 |
| 18 | P. Gauvreau, Quebec, Canada | 234 | 8 | 47 | 2 |
| 19 | Riga Cement Co., by C. X. Schmidt, Riga, Russia | 230 | 6 | 44 | 2 |
| 20 | Anchor Cement, by Coplay Cement Co., Coplay, near Allentown, Pa., United States | 208 | 12 | 41 | 3 |
| 21 | Cumberland Hydraulic Cement Co., Cumberland, Md., United States | 196 | 12 | 41 | 3 |
| 22 | Société Anonyme des chaux éminemment hydrauliques de l'Homme d'Armes, près Montélimar, France | 184 | 7 | 29 | 2 |
| 23 | Howe's Cave Association, Howe's Cave, N. Y., United States, No. 1 | 183 | 6 | 28 | 2 |
| 24 | " " " " " No. 2 | 170 | 10 | 43 | 2 |
| 25 | " " " " " No. 3 | 170 | 8 | 31 | 2 |
| 26 | Società Anonima per la fabbricazione del cemente, provincia di Reggio, Emilia, Italy, 1st quality | 181 | 12 | 27 | 3 |
| 27 | Società Anonima per la fabbricazione del cemente, provincia di Reggio, Emilia, Italy, 2d quality | 154 | 12 | 22 | 3 |
| 28 | Thomas Gowdy, of Limehouse, Ontario, Canada | 126 | 8 | 23 | 2 |
| 29 | A. H. Lavers, London, England | 122 | 6 | 24 | 2 |
| | SCOTT'S SELENITIC CEMENT. | | | | |
| 30 | Patent Selenitic Cement Co., London, Eng. (made with Howe's Cave lime and plaster) | 298 | 20 | 52 | 5 |
| | PARIAN CEMENTS. | | | | |
| 31 | Francis & Co., London, England, 1st quality | 1,175 | 8 | 181 | 3 |
| 32 | " " " 2d quality | 606 | 12 | 169 | 3 |
| 33 | A. H. Lavers, London, England | 205 | 6 | 51 | 2 |

* This cement appeared to be inferior in hydraulic energy to Roman cement generally, and had probably been injured by age and exposure.

All the cements exhibited at the Centennial Exposition were carefully tested before awards were recommended, by mixing them dry in each case with an equal measure of clean sand, tempering the mixture with water to the consistency of stiff mason's mortar, and then moulding it into briquettes of suitable form for obtaining the tensile strength on a sectional area 1½ inch square, equal to 2¼ square inches. The briquettes were left in the air one day to set, then immersed in water for six days, and tested when seven days old. After thus obtaining the tensile strength in each case, the ends of the broken specimens were ground down to 1½-inch cubes, which were used the same day for obtaining the compressive strength by crushing. The results, averaged from a number of trials with each sample of cement, and divided by 2¼ in order to get the strength per square inch, are recorded in the preceding table.

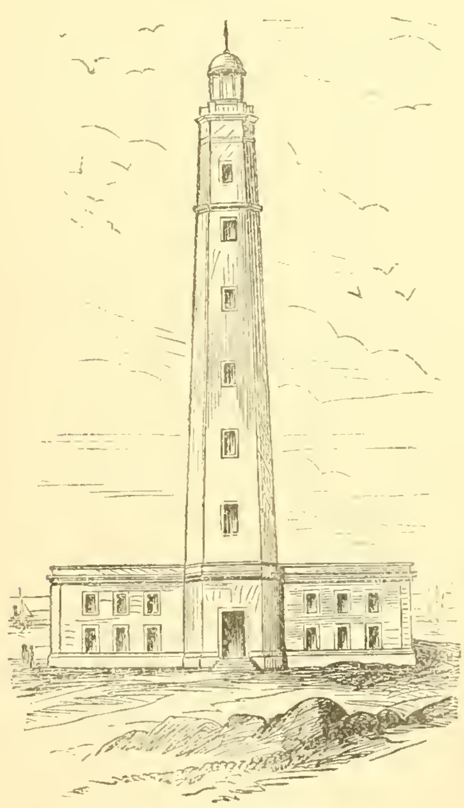
*Teil Hydraulic Concrete Stone.*—The Teil stone manufactured by the Fire-proof Building Company of New York consists of artificial blocks of Teil hydraulic concrete.

The hydraulic lime of Teil is preëminently a hydraulic cement, containing 66 per cent. of silicate of lime. It is mixed with sand, pebbles, broken stone, etc., and the concrete thus formed hardens equally well under water as in the air. Its strength increases with age. The crushing strength of Teil hydraulic mortars, according to well-authenticated experiments, is 220 lbs. per square inch at the end of 45 days, and 614 lbs. when 2 years old. Their tensile strength is 41 lbs. per square inch at the end of 45 days, and 164 lbs. after 2 years. In artificial blocks of stone of various compositions, in which Teil hydraulic lime is largely used, the crushing strength varies from 2,600 to 7,500 lbs. per square inch, and the tensile strength from 288 to 426 lbs.

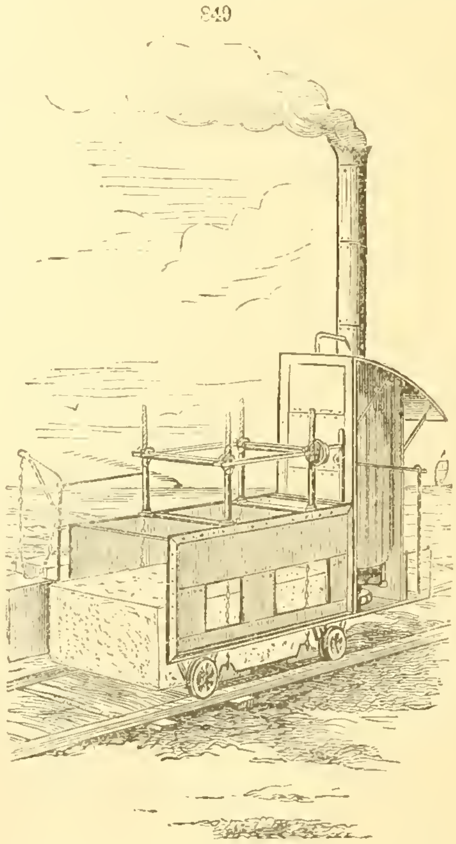
Blocks of Teil hydraulic concrete 10 feet long, 6 feet wide, and 6 feet high, weighing 25 tons each, are used in the construction of sea-walls, piers, etc. They are placed in regular courses like masonry, and form a wall of great strength. (See Breakwater.)

This material is also suitable for the construction of lighthouses, for which it can be made in separate blocks for masonry, or the building of whatever size can be built of a single mass without any joints. The lighthouse of Port Said, Fig. 848, is built in this way of one mass of Teil concrete; it

848.



849



is 180 feet high, and rests on a Teil concrete base of 400 cubic yards. Fig. 849 represents the carriage used for transporting the heavy concrete blocks from place to place.

Cements for Various Purposes.—Air and water-tight, for casks and cisterns: Melted glue 8 parts, linseed-oil 4; boil into a varnish with litharge. This hardens in 48 hours. Plumbers': Black resin 1 part, brick-dust 2. Melt together. For leaky boilers: Powdered litharge 2 parts, fine sand 2, slaked lime 1. Mix with boiled linseed-oil. Apply quickly. Acid-proof: A paste of powdered glass and concentrated solution of water-glass. Cutler's: 1. Pitch 4 parts, resin 4, tallow 2, and brick-dust 2. 2. Resin 4, beeswax 1, brick-dust 1. 3. Resin 16, hot whiting 1, wax 1. This is used for fastening blades in handles. For ivory or mother-of-pearl: Isinglass 1 part, white glue 2, dissolved in 30 parts hot water and evaporated to 6 parts. Add gum-mastic $\frac{1}{30}$ part, dissolved in one-half part alcohol, and add 1 part zinc-white. Shake up and use warm. Jeweler's, for uniting all substances: Gum-mastic 5 or 6 bits as large as a pea, dissolved in spirits of wine sufficient to render all liquid. In another vessel dissolve the same amount of isinglass in rum enough to make 2 ounces of strong glue, adding 2 small pieces of gum ammoniacum, which must be moved until dissolved. Heat and mix the whole. Keep in a closely-corked phial, and put the latter in boiling

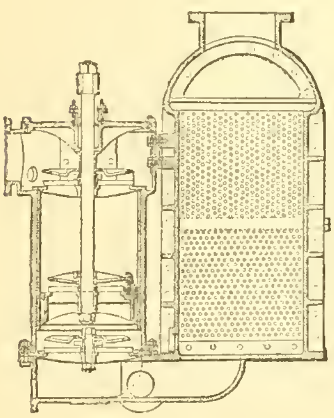
water before using. Black, for bottle-corks: Pitch hardened by the addition of brick-dust and resin. For jet: Use shellac, warming the edges before applying, and smoke the joint to make it black. For meerschaum or china: 1. Make a dough of garlic, rub on the edges, and bind tightly together. Boil the object for half an hour in milk. 2. Use quicklime mixed to a thick cream with white of egg. Soft, for steam-boilers: Red or white lead in oil 4 parts, iron borings 3 parts. Gas-fitters': Resin $4\frac{1}{2}$ parts, wax 1, Venetian red 3. Coppersmiths': Boiled linseed-oil and red lead made into a putty. This is used to secure joints and on washers. For emery on to wood: Equal parts of shellac, white resin, and carbolic acid in crystals. Add the acid after the others are melted. Iron and emery: Coat the metal with oil and white lead, and when hard apply the emery mixed with glue. French putty, hard and permanent: Linseed-oil 7 parts, brown umber 4, boiled for 2 hours, one-eighth part white wax stirred in. Remove from fire and thoroughly mix in white lead 11, and fine chalk $5\frac{1}{2}$ parts. India-rubber: Fill a bottle one-tenth full of native India-rubber cut into fine shreds. Pour in benzole from coal-tar till the bottle is three-fourths full. The rubber will swell; and if the whole be shaken every few days, the mixture will become as thick as honey. If too thick, add benzole; if thin, add rubber. This dries in a few minutes, and will unite backs of books, straps, etc., very firmly. Chinese, for fancy articles, wood, glass, etc.: Finest pale-orange shellac, broken small, 4 parts, rectified spirit 3 parts. Keep in a corked bottle in a warm place until dissolved. It should be as thick as molasses. Rust-joints: 1. Clean iron borings 2 parts, flowers of sulphur $\frac{1}{16}$, sal-ammoniac $\frac{1}{16}$. 2. Finely-powdered iron borings 1 part, sal-ammoniac $\frac{1}{8}$, flowers of sulphur $\frac{1}{16}$. Pound together and keep dry. For use, mix 1 part with 20 of pounded iron borings, and mix to a mortar consistence with water. For making metallic joints sound: 1. Use a putty of boiled linseed-oil and red lead. 2. Use a putty of equal parts of white and red lead. For electrical and chemical apparatus: Resin 5 parts, wax 1, red ochre 1, plaster-of-Paris $\frac{1}{8}$. Melt at moderate heat. For mending stone, or as mastic for brick walls: Make a paste of linseed-oil with clean river-sand 20 parts, litharge 2, quicklime 1. For chucking work in the lathe: 1. Black resin 8 parts, yellow wax 1; melt together. For use, cover the chuck to one-sixteenth of an inch thick, spreading over the surface in small pieces, mixing it with one-eighth of its bulk of gutta-percha in thin slices. Heat an iron to dull red, and hold it over the chuck till the mixture and gutta-percha are melted and liquid. Stir the cement with the iron until it is smoothly mixed. Chuck the work, lay on a weight to enforce contact, and let it rest for half an hour before using. 2. Burgundy pitch 2 parts, resin 2, yellow wax $\frac{1}{8}$, dried wax 2. Melt and mix. 3. Resin 4 parts, melted with pitch 1. While boiling add brick-dust until dropping a little on stone shows the mixture to be sufficiently hard. Elastic, for leather or India-rubber: Bisulphide of carbon 4 ounces, shredded India-rubber 1 ounce, isinglass 2 drachms, gutta-percha $\frac{1}{2}$ ounce. Dissolve, coat the parts, dry, then heat the layer to melting, place and press the parts together. Water-tight, for wooden vessels: Lime, clay, and oxide of iron, mixed, kept in a close vessel and compounded with water for use. For leather, straps, etc.: Gutta-percha dissolved in bisulphide of carbon. Keep tightly corked and cool. It should be of the consistence of molasses. For marble, or for attaching glass to metal: Plaster-of-Paris soaked in a saturated solution of alum and baked hard. Grind to powder and mix with water for use. Can be colored to imitate any marble, and takes a fine polish. Impervious, for corks, etc.: Zinc-white rubbed up with copal varnish. Give two coats so as to fill all the pores, and finish with varnish alone. For cracks in wood: 1. Slaked lime 1 part, rye meal 2, and linseed-oil 2. 2. Use a paste of sawdust and prepared chalk with glue 1 part, dissolved in water 16. 3. Oil-varnish thickened with equal parts of litharge, chalk, and white and red lead. For wood and glass or metals: 1. Resin and calcined plaster, the former melted, made into a paste. Add boiled oil to consistence of honey. 2. Dissolved glue and wood-ashes to consistence of varnish. Fire-proof and water-proof: Pulverized zinc-white, sifted peroxide of manganese, equal parts. Make into a paste with soluble glass. To mend iron pots and pans: Partially melt 2 parts sulphur, and add 1 part fine black lead. Mix well, pour on stone, cool, and break in pieces. Use like solder with an iron. London cement, for glass, wood, china, etc: Boil a piece of cheese three times in water, each time allowing the water to evaporate. Mix the paste left with quicklime. For aquaria: 1. For fresh-water aquaria: Take $\frac{1}{2}$ gill gold-size, 2 gills red lead, $1\frac{1}{4}$ gill litharge, and sufficient silver sand for a thick paste. This sets in about 2 days. 2. For fresh or salt water: Take $\frac{1}{2}$ gill powdered resin, 1 gill dry white sand, 1 gill litharge, 1 gill plaster-of-Paris. Sift; and for use mix with boiled linseed-oil, to which a little dryer has been added. Mix 15 hours before using, and allow 2 or 3 hours to dry. For petroleum lamps, impervious to the oil: Resin 3 parts, boiled with water 5 and caustic soda 1. Then mix with half its weight of plaster-of-Paris. This sets in three-quarters of an hour. Roman: Green copperas $3\frac{1}{2}$ lbs., slaked lime 1 bushel, fine gravel-sand 1 bushel. Dissolve the copperas in hot water, and mix all to proper consistence. Keep stirred. Glass to glass, for sign-letters, etc.: Melt in a water-bath liquefied glue 5 parts, copal varnish 15, drying-oil 5, oil of turpentine 2, turpentine 3. Add slaked lime 10. Hydraulic: Oxide of iron 1 part, powdered clay 3, and boiled oil to a stiff paste. Stone: Sand 20 parts, litharge 2, quicklime 1, mixed with linseed-oil. Leather and cloth, for uniting parts of boots and shoes, seams, etc.: Gutta-percha 16 parts, India-rubber 4, pitch 2, shellac 1, oil 2. Mix and use hot. Mahogany: Shellac melted and colored. Colorless, for paper: Add cold water to rice-flour, mix, bring to proper consistence with boiling water, and boil one minute. Water-proof, for cistern stones: 1. Whiting 100 parts, resin 68, sulphur $18\frac{1}{2}$, tar 9. Melt together. 2. Sand 100 parts, quicklime 8, bone ashes 14, mixed with water. Transparent: India-rubber 75 parts, chloroform 60. Mix, and add mastic 15. Cloth to iron: Soak the cloth in a dilute solution of galls, squeezing out the superfluous moisture, and applying the cloth, still damp, to the surface of the iron, which has been previously heated and coated with strong glue. The cloth should be kept firmly pressed upon the iron until the glue has dried. For cracks in stoves: Finely-pulverized iron (procured at a druggist's) made into a thick paste with water-glass. The hotter the fire, the more the cement melts and combines, and the more completely does the crack become closed.

For china, glass, etc.: 1. Diamond cement, for glass or china, is nothing more than isinglass boiled in water to the consistence of cream, with a small portion of rectified spirit added. It must be warmed when used. 2. White lead rubbed up with oil. Articles mended with this must stand for a month. For corks of benzine-bottles: A paste of concentrated glycerine (commonest kind) and litharge. This soon hardens, and is insoluble in benzine or any of the light hydrocarbon oils. For caustic lye tanks: The tanks may be formed of plates of heavy spar, the joints being cemented together by a mixture of 1 part finely-divided India-rubber dissolved in 2 parts turpentine oil, with 4 parts powdered heavy-spar added. Colored: Soluble glass of 33° B. is to be thoroughly stirred and mixed with fine chalk and the coloring matter well incorporated. In the course of 6 or 8 hours a hard cement will set. The following are the coloring materials: 1. Black: well-sifted sulphide of antimony. This can be polished with agate to a metallic lustre. 2. Gray-black: fine iron-dust. 3. Gray: zinc-dust. This has a brilliant lustre, and may be used for mending zinc castings. 4. Bright green: carbonate of copper. 5. Dark green: sesquioxide of chromium. 6. Blue: Thénard's blue. 7. Yellow: cadmium. 8. Bright red: cinnabar. 9. Violet red: carmine. 10. Pure white: fine chalk as above.

*Works for Reference.*—"On Calcareous Cements and Quicklime," Higgins, London, 1780; "Mémoire sur les Mortiers Hydrauliques," Treussart, Paris, 1829; "On Calcareous Mortars and Cements," Vicat, 1837; "On Limes, Calcareous Cements, Mortars," etc., Pasley, London, 1847; "Praktische Anleitung zur Anwendung der Cemente," Becker, Berlin, 1861–'68; "Practical Treatise on Limes, Hydraulic Cements, and Mortars," Gillmore, New York, 1863; "On Limes, Cements, and Mortars," Burnell, 1868; "Die Hydraulischen Mörtel," Michaelis, Leipsic, 1869; "Traité sur l'Art de faire de bons Mortiers," Charleville, Paris; "On Calcareous and Hydraulic Limes and Cements," Austin, New York, 1871; "Experiments on the Strength of Cements," Grant, London, 1875; "Portland Cement, its Manufacture and Uses," Reid, London, 1877. See also "Reports of Commissioners to Paris Exposition," 1867.

CONDENSERS. When the exhaust steam from an engine is to be condensed, it can be brought into direct contact with the condensing water, or passed over surfaces which are cooled by water or air. In the first form, or jet condenser, the exhaust steam mingles with the condensing water; while in the surface condenser the fresh water resulting from the condensation can be used to feed the boilers. At the present time, when steam of considerable pressure is used at sea, it is of great importance to use fresh water in the boilers, since water deposits solid impurities much more rapidly as its temperature is increased; and nearly all modern ocean steamers are provided with surface condensers. With either form of condenser, as ordinarily constructed, an air-pump is required, to remove the air and vapor; and the surface condenser is provided in addition with a circulating-pump, to force water rapidly around the condensing surfaces. The general arrangement of a surface condenser, such as is used in connection with marine engines, is shown in Figs. 850, 851, and

850.



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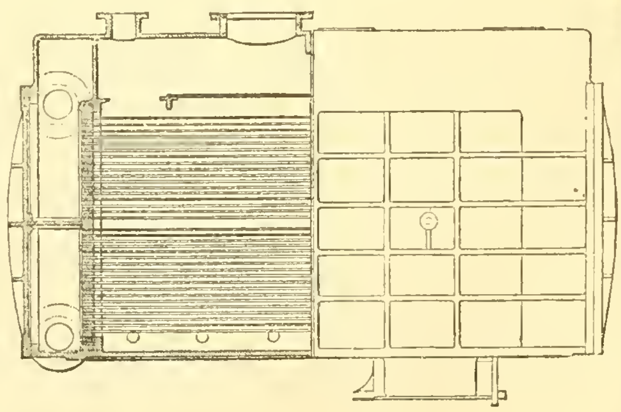

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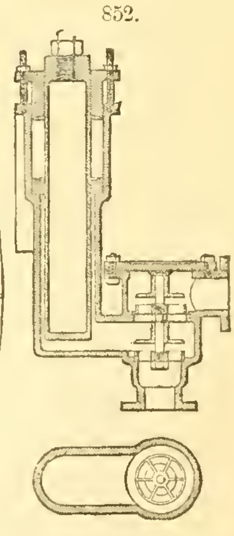

852. It consists of a number of tubes within a box or case. The exhaust steam passes around the tubes, and the water of condensation is removed by the air-pump shown in Fig. 850. Cold water is pumped through the tubes to condense the steam by a circulating pump, Fig. 852. In practice there are, of course, many modifications of this general principle. Sometimes the exhaust steam passes through the tubes and the condensing water circulates around them; and independent air and circulating pumps driven by small engines are often employed. (See Engines, Steam, Marine.)

Some interesting notes on surface condensers, descriptions of early forms, and general discussions, may be found in the "Transactions of the Society of Engineers," 1862, and "Transactions of the Institution of Engineers in Scotland," vols. iv., v., and xi.

There are a number of condensers, designed principally for use in connection with land engines, that require no air-pumps. Prominent among these are Morton's ejector condenser and those of the same class, which are described in the "Transactions of the Institution of Civil Engineers," 1872, and the "Transactions of the Institution of Engineers in Scotland," 1868, 1869. The papers referred to contain much interesting and useful information. The minimum amount of condensing water required in any particular case can be calculated by table I. under Expansion of Steam and Gases. Suppose the pressure of steam when discharged into the condenser is 10 lbs. above zero, that the initial temperature of the injection water is 70° F., and the final temperature 115°. By column 7

in the table referred to, each pound of steam on being condensed must be deprived of 1141 — 83 = 1058 units of heat, and each pound of water takes up 115 — 70 = 45 units; so that the least quantity of water necessary to condense a pound of steam is $\frac{1058}{45} = 23.5$ lbs. In order to render all the condensing water available, it should be brought into as intimate connection with the steam as possible. To this end, in jet condensers, the condensing water is frequently introduced as spray and falls on a scattering plate, while in surface condensers the passages are small, so that the water shall move rapidly and be divided up into small portions, each one of which will receive heat quickly; and if it were not for the increased resistance to the passage of the water that follows from decreasing the area, it might be advantageously subdivided to a much greater extent than obtains in practice.

The size of a jet condenser, according to ordinary practice, is about one-third of the volume of the cylinder. In proportioning surface condensers, a very ordinary rule is to make the condensing surface three-fourths of the boiler-heating surface; but there are condensers in use having a much less proportion of surface. There are examples of surface condensers condensing 10 lbs. of steam per hour per square foot of surface; but the more usual practice is probably between 4 and 6 lbs. The efficiency of a condenser depends of course on the manner and velocity with which the condensing water passes through it, as well as upon the thickness of the condensing surfaces. In some experiments by Mr. Joule, where each condensing tube was surrounded by another tube and water was driven in one direction through the annular space, while steam passed through the tube, as much as 100 lbs. of steam were condensed per hour per square foot of tube surface (Rankine's "Treatise on the Steam Engine," p. 266); and in *Engineering* for Dec. 10, 1875, is an account of some experiments in which this rate of condensation was exceeded.

It has been proposed to use air for condensing steam, instead of water, and condensers have been constructed on this principle. The efficiency of such a condenser obviously depends on the velocity with which the air is brought into contact with the condensing surface; and in one form of air condenser the condensing surface was made to revolve, after the manner of a fan. For notes on the theory of air condensation, account of an experimental condenser, and experiments on the heat received by air at different velocities, see *Van Nostrand's Eclectic Engineering Magazine*, i., 527; the *Scientific American*, x., 265; and the *Engineering and Mining Journal*, xxiv., 259. R. H. B.

CONE-PLATE. See LATHE AND DRILL CHUCKS.

CONE-PULLEY. See BELTS.

CONFORMATOR. An apparatus used by hatters to obtain the shape of the head. It has the form of a hat brim and crown, and is composed of 60 small branches of ebony held close to the frame in which they slide by a brass spring wire. When not in use, the inner arms of these branches together form an elliptical cavity; but when the conformator is placed on the head, every projection thereon pushes the branches more or less outward, the wire spring yielding and the cavity assuming an irregular shape. Upper inner arms of the branches form an elliptical-shaped aperture in the crown of the apparatus, which assumes the same shape as that impressed upon the branches themselves. On these arms are steel points, upon which a piece of paper is pressed, and which thus mark on the paper the exact conformation of the wearer's head reduced in scale. The piece bounded by the indented line is then cut out, and placed in a device consisting of numerous branches, which are slid inward until they touch the edge of the paper on all sides. They are then secured in place, and their outer surfaces form a block exactly corresponding in shape to the head measured. Over the block the hat after being warmed is pressed, and thus caused to fit. This device was invented by M. Allié of Paris in 1843. See *Scientific American*, xxxviii., 143.

CONVERTER. See STEEL.

COPE. See PATTERN-MAKING AND MOULDING.

CORK-CUTTING MACHINERY. Cork is the soft cellular interior bark of the *Quercus suber*, a species of oak indigenous to Spain and Portugal. It is removed from the tree by making several longitudinal clefts up and down the trunk, and then girdling the latter with horizontal incisions. The first crop is not gathered until the tree has attained the age of 15 years, and is employed only for inferior purposes. Seven years afterward the tree will have another coating of bark, which is stripped, and a new supply is thereafter gathered about every 6 years. After the stripping the cork is inspected and assorted according to size and quality, that of the finest texture being most valuable. The inferior portions are generally sorted out, their crust burned off, and sold mostly for floats, hence receiving the name of fishing-cork. The better qualities are first boiled and scraped, and then blackened over a coal-fire, the object being to make the surface smooth and at the same time to conceal flaws. After being forwarded to the warehouse, the largest slabs are cut into pieces of about 3½ feet in length, 18 inches in width, and ranging from half an inch to 3 inches in thickness. Drying and packing in bales weighing 150 lbs. each follows, and the cork is ready for exportation.

In this country, after the cork is received at the factory, it undergoes another assorting, and a thorough steaming in a chest designed for the purpose, the latter process softening the cork and rendering it easy to cut. Various machines have been devised for cork-cutting. In one, rapidly-revolving circular knives are used, which cut by a drawing motion, as crushing strokes simply break the cork or cause it to crumble. The workman, sitting in front of the machine, places a piece of cork of suitable size in a revolving spindle, by which it is firmly held. The spindle is raised a measured distance, and the edges of the cork come in contact with the rotating knife, which smooths them off, leaving the material in perfectly cylindrical form. Another method is to place the rough bits of cork in grooves on the circumference of a wheel, which, working automatically, carries each piece to a point where its ends are received by a small lathe. The cork is then revolved slowly, while a large circular knife removes a thin shaving, thus giving it the necessary taper and a smooth

and true surface. As soon as a cork is finished by the automatic lathe, it is released and another substituted.

Figs. 853 and 854 represent one of the latest improved machines for cork-cutting. The cork from the bale is first passed to the machine, in which *A* is an iron table bolted to a wooden one by means of the brackets *D* and *E*; *B* is a guide-piece, and *C* is a revolving disk of steel, similar to a circular saw, but having the edge sharp, the bevel of the blade being all on the outside, so that the cork shall not jam. The pieces of cork from the bale are laid upon the table *A*, and kept against the guide or gauge *B*, whose distance from the knife regulates the width of the strips the cork is cut into. The cork strips next pass to the machine shown in Fig. 854, in which *A A A A* represent a revolving spindle, driven by the pulley *B* and fitting easily, and capable of being slid or moved horizontally back and forth through the bearings provided in the standards *C C*. Upon one end of *A* is the flange *D*, which passes down into a recess provided in the lever *E*, so that if the latter is operated laterally the spindle *A A A A* will also be operated laterally. *I* is the cutter, which is formed of a hollow piece of cast-steel tube, parallel in its bore, and with a sharp edge produced by beveling off the outside. *F* represents a round spindle, which passes through the revolving spindle *A A A A*, the latter being made hollow to receive the former. The spindle *F* protrudes into and nearly through the cutter *I*. It is supported and regulated in its distance up the spindle *A A A A* by the hand-screw *H*, which screws it to the face of the bracket *G*, that end of the spindle *F* being flat and provided with a long slot. *J* is a tail-stock or back-head, adjustable by the screw-handle *M*, the upper part of *J* being a block of hard wood denoted in the drawing by *K*. The gauge *L* is adjustable by a nut, as shown. The operator places a strip of cork on the gauge *L*, and, while the machine is running at a high speed, he pulls toward him the handle *E*, thus forcing the cutter through the cork and up against the wood block *K*. He then moves the handle *E* back again, which withdraws the cutter, carrying the cut cork in the bore of the cutter until the cork meets the end of the stationary spindle *F*, which retains it, and the cutter, passing back, leaves the cork, which falls down. After the machine is once set, therefore, the operator has nothing to do but to feed the cork strips with one hand, and operate back and forth the handle *E* with the other hand.

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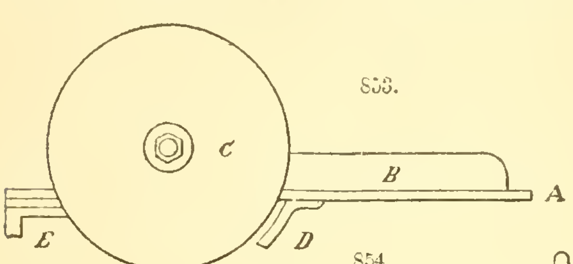


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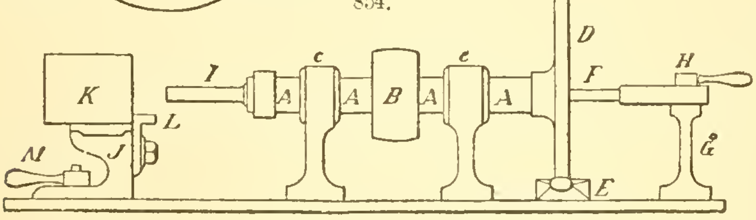


To taper the corks, they are fed by hand in a horizontal position down an inclined trough to a vertically-operated plunger, having its upper end hollowed to receive a cork, which drops into this hollow when the plunger is at the bottom of its stroke. It is then carried up by the plunger and held for an instant horizontally level with a rapidly revolving spindle, similar to a lathe-spindle, but having a flat and solid end; then a stationary spindle, answering to the dead centre of a lathe, approaches and forces the end of the cork against the revolving spindle, which by friction revolves the cork. At the back of the position now held by the revolving cork, and lying in a plane inclined to the plane of the length of the cork, is a large revolving steel disk, similar in form to that shown at *C*. This steel blade, while revolving at a high speed, is traversed over the top of the revolving cork, cutting it taper and of the necessary diameter from end to end at one cut. As soon as the cork is thus turned, which takes but a second, the driving mandrel recedes and releases it, the plunger falls, carrying the cork with it, and while the cork falls below the machine the cork-cuttings are carried by the revolving cutter to the back of the machine, as follows: from where the cutting operation is performed for about one-third of the circumference of the disk-knife it is provided with a guard, which retains the cuttings upon the knife, but on leaving the guard the centrifugal force throws the cuttings off and into a box provided to receive them. The capacity of each of these machines is about 250 gross per day.

An ingenious cork-cutting machine, the invention of M. A. Robert, was exhibited in the Paris Exposition of 1878. The sheet of cork is first cut into square blanks approximating the finished cork in size. These are fed down, one at a time, between vertical guides, and descend upon a table, where they are met by a clamp, which grasps them and pushes them forward between spindles, the under one of which is spiked and the upper one toothed. While held in these the cork is rotated on its vertical axis against a swiftly-moving band-saw blade about 2 inches in width. This blade is constantly in motion, and in order to keep it sharp a horizontal grindstone is provided. The stone is actuated at intervals by a cam-wheel driven by a worm and pinion from the main shaft, so that at every revolution of the latter the grindstone is brought into contact with the blade and rotated for a few seconds.

The same inventor also exhibited a small machine in which a knife was moved to and fro by hand. Strings attached to the knife-handle, which ran on guides, rotated the spindles between which the cork was secured.

COTTER. See Gib and Cotter.

COTTON-GIN. A machine for cleansing cotton and preparing it for the market or for carding. The most simple as well as the most ancient cotton-gin is the roller-gin, which consists of fluted rollers about five-eighths of an inch in diameter, and from 9 to 16 inches long, placed parallel in a

frame, which keeps them almost in contact. The rollers revolve in opposite directions; the cotton is drawn through between the rollers, while the seeds are prevented from passing by the narrowness of the space. This machine is still used for the finer and longer-stapled cottons, but the operation is tedious and expensive; and the saw-gin, invented by Eli Whitney in 1793, from its general use, its wondrous effects on the extension of cotton cultivation, and its influence on manufactures and commerce, may now claim distinction and consideration almost exclusively as the cotton-gin. In its main features this machine still continues as first invented by Whitney; but in various details and workmanship it has been the subject of many improvements. Fig. 855 presents a perspective view of an improved cotton-gin, and Fig. 856 is a section of the same. In the latter, *a* is the grate-fall head, or end of breast; *b*, seed-board; *c*, saw-cylinder; *d*, saw; *e*, "patent detached grate;" *f*,

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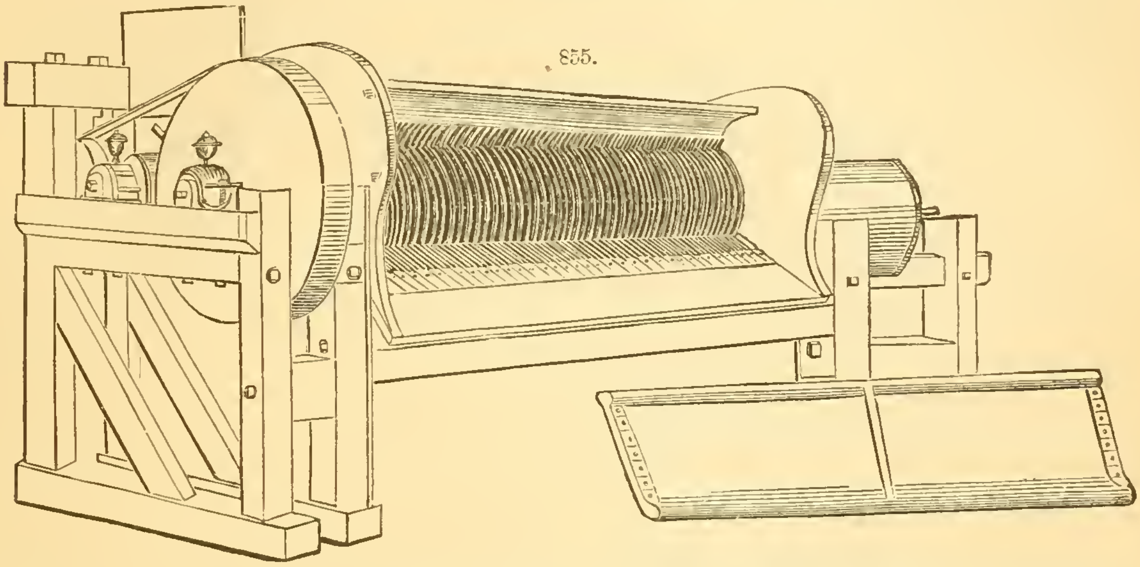

screw or bolt on which the grate-fall rests; *g*, back board, to which are attached the back grates and "patent moter;" *h*, grate-fall hollow, which is hung upon hinges, and may be raised or lowered at pleasure; *i*, sliding-butt, by means of which the saw-tooth may be made to assume any desired angle with the curved surface or front of the grate; *j*, "patent brush;" *k*, sliding mote-board; *l*, bottom board.

The grate-fall, or breast, into which the seed-cotton is thrown, is formed with ends or heads of cast-iron, and pear-shaped, the lower and back side being composed of cast-iron grates, screwed firmly to the wood-work of the breast; the saws project through the interstices between the grates from 1 to 2 inches; the upper and back part of the grate-fall, called the "hollow," is hung upon hinges, and may be raised or lowered at pleasure, and fastened in any desired position by joint-bolts through the grate-fall heads.

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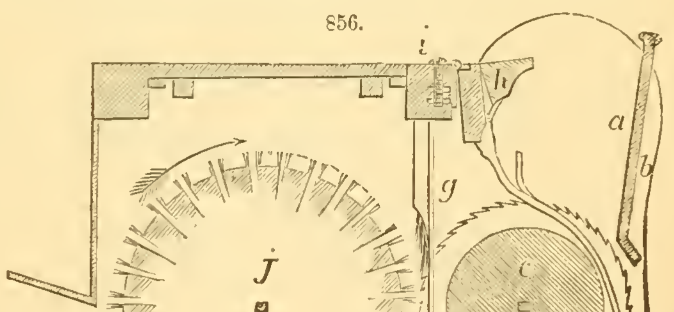


The seed-board makes the front part of the breast, and stands nearly perpendicular, leaving a space between it and the grates for the discharge of the seed; it is hung upon pivots at the top at each end, so that the bottom may be swung outward and the hopper emptied at any time. When in place the bottom is fastened by small slide-bolts. The position and angle of the seed-board may be readily varied and adjusted, by altering the position of the slides upon which the pivots rest. These slides are fixed to the grate-fall heads by small bolts passing through slots, having a nut outside.

The grate-fall, or breast, is hung to the front top timber of the frame by stout hinges above the saw-cylinder, and the lower part rests upon two short screws in the front piece. That part of the hinge or butt which is attached to the top timber is so fixed as to slide up or down by means of slots and an adjusting screw, and is fastened in the desired position by bolt-nuts.

The saw-cylinder is made of wooden staves, about 2 inches thick, upon an iron shaft, and turned in a lathe of a uniform diameter; and by the application of a small saw, when in the lathe, grooves are formed to receive the saw-segments, which are made of the best cast-steel, and inserted and fastened into these grooves.

There is a set of wooden grates behind the saw-cylinder, and a row of hair or bristles, called the "moter," to separate the false seeds, motes, and dirt from the ginned cotton.

The brush is made of about 20 inches diameter, cylindrical, having slits lengthwise between the rows of bristles and a hole around the shaft to receive the air as the brush revolves; and a rapid centrifugal motion is given to the air, which is forced out with great power between the rows of bristles.

Behind the brush is an opening, the length of the frame, into the lint-room, and beneath the brush a sliding board, called the mote-board, which may be slid back or forward for the purpose of regulating the draft of the gin, and properly separating the motes, dirt, and leaf from the clean cotton.

In the saw-gin, as ordinarily constructed, the cotton is liable to collect in the spaces or interstices between the grates, and around them above the saws, thus choking or clogging the grates, and preventing the rising and free escape of the roll of seed-cotton. The patent detached grate, instead of being attached directly to the wood part of the breast at the top, has an arm or brace extending out behiud, through which it is screwed to the wood, so that the top of the grate stands out and is detached from the wood, and has a space behind of a quarter inch or more between it and the wood, and also a space between it and the adjacent grates; so that there is no chance for the cotton to collect above the saws, and the choking is entirely avoided.

Many efforts have been made to improve the saw-gin, so as to separate motes and other impurities from the fibres of cotton. By some this has been essayed by means of rotating brushes acting on the fibres, and carrying them from the grate to the stripping-brush, rotating in a reverse direction to the saws. Some have used stationary brushes, through which the saws carry the fibres to be stripped of motes and other impurities. The objection to these is that they act on the cotton only when upon the teeth of the saws, and therefore, instead of separating the motes and other impurities from the fibres to which they adhere, sometimes with considerable tenacity, the fibres are drawn out with the motes, thus occasioning considerable loss of cotton. The object of the moter is to avoid this loss, and to hold on to the motes or other impurities, as the fibres are stripped from the saws by the stripping-brush, the fibres being under the operation of both brushes at the same time. The moter also more effectually stops the current of air generated by the rotation of the stripping-brush from acting on the fibres before they are cleaned, than if located at a greater distance from the point of action of the stripping-brush.

*The Macarthy Gin* is designed to clean large quantities of cotton expeditiously without occasioning any injury to the staple. The cotton is drawn, by a leather roller having shallow diagonal grooves which will not admit of the passage of a seed, between a metal plate called the "doctor," fixed tangentially to the roller, and a blade called the beater, moving up and down in a plane immediately behind and parallel to the fixed plate. While the cotton is drawn through by the roller, the seeds are forced out by the action of the movable blade. Numerous modifications of this gin have been made, and in some cases the movable blade or knife is made to work horizontally instead of vertically. The double-action gin has a double set of knives, set so as to balance each other, each revolution of the crank giving two strokes of the knife.

*The Cowper Lock-Jaw Gin.*—In this machine the jaw which locks fast the cotton fibre is formed by the nipping-blade, which is caused to approach and nip the fibre on the roller at the time it is traveling at the same surface speed and in the same direction. While the fibre is so held, the beater acts on and pushes away the seeds close to the nipping-blades, and separates them from the fibre close to the seed. The nipping-blade then returns to its former position, moving in the opposite

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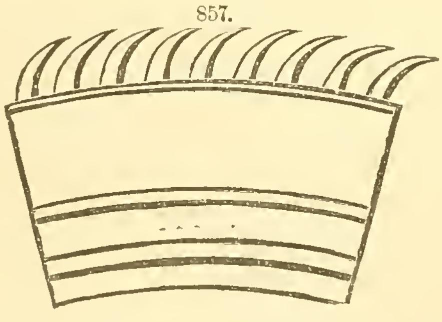

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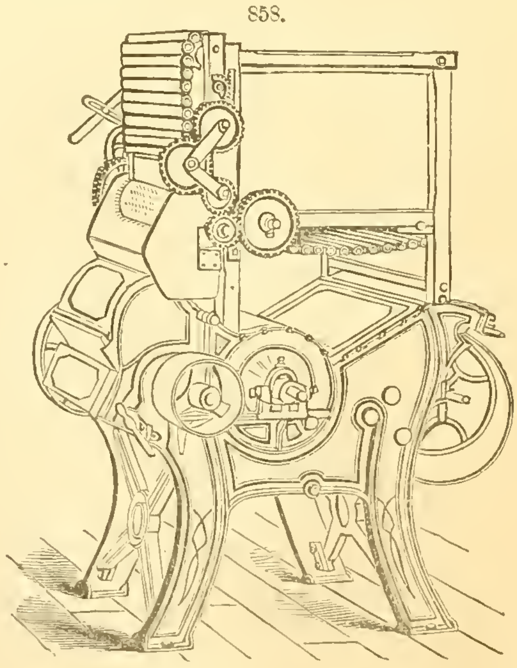

direction to the surface of the roller. A fresh supply of cotton is then drawn in and grasped, when the nip is repeated.

*The Knife-Roller Gin.*—This has the same roller as the Macarthy gin, with the steel blade or pressing knife pressed against its surface by springs and screws. A knife-roller is substituted for the beater-plate used in the Macarthy machine. It consists of a spindle carrying oval plates of about 5 inches in diameter. These plates are placed diagonally with the axis on which they are fixed; and being oval, when caused to revolve the blades or knives draw the cotton-seed alternately right and left along the edge of the pressing knife, while the ginning roller pulls away the fibre from the seed and it falls through a grating. There is a guard which prevents the seed from being broken between the ginning roller and the edges of the knives on the knife-roller.

*The Scattergood Needle-Gin.*—A notable improvement has been made in Scattergood's "needle-gin," in which the teeth are needle-pointed, and set in Babbitt metal, causing less injury to the staple than the old saws. The circles or rings of teeth are each composed of 10 sections, one of which can be easily replaced when injured. One of these gins, of 50 rows of teeth, will gin a bale of cotton per hour, and requires about 5 horse-power. The method of setting the teeth is shown in Fig. 857. The bent teeth necessary to form a section are placed in a mould, and the soft metal poured around them. The number of sections (10) required for a circle are then placed between two iron disks of the proper diameter, which fit into a groove on the section, and an axial hole in which also fits on the central shaft. This process is repeated until the desired length of cylinder is obtained, when by means of a screw cut on the shaft, and its proper nut, the whole cylinder is firmly drawn together.

This gin, having two-fifths more space between the teeth than the saw-gin for the same number of teeth, will at the same velocity clean a larger amount of cotton, while the rounded teeth will not injure the staple like those of the saw. It has also a self-acting feed-motion.

The machine, Fig. 858, has a box occupying the top of the gin. An endless rotating apron of slats forms the bottom, while an upright endless rotating apron of slats forms the front, and a rotating toothed roller forms the lower front corner. The lower apron brings the seed-cotton forward and against the toothed roller; the roller, having a slightly accelerated motion, seizes the cotton and carries it over itself, when it drops into the hopper of the gin. The upright apron lifts the superfluous cotton up and away from the roller, and keeps turning the whole mass of seed-cotton in the hopper over, thereby shaking out much of the dirt and sand and opening the cotton; by its action all tendency of the cotton to jam and choke in the machine is avoided. An easy adjustment of the upright apron changes the feed at the will of the operator.

*Table showing claimed Capacity of various Cotton-Gins.*

| NAME OF GIN. | Size. | Pounds of Cotton cleaned per Hour. | REMARKS. |
|---|---|---|---|
| Whitney........................ | 80-saw. | 90 | |
| Macarthy, hand machine......... | 12-inch. | 8 to 12 | |
| Same, single action.............. | 40 " | 25 to 50 | |
| Same, self-feeding, double action.. | 40 " | 30 to 80 | Maximum on long-stapled cotton. |
| Cowper lock-jaw, power......... | 30 " | $48\frac{3}{4}$ to 76 | " " " |
| " " hand.......... | 14 " | $21\frac{3}{4}$ to 35 | " " " |
| Knife-roller...................... | 40 " | 50 to 150 | |

For an account of a trial of cotton-gins in Manchester, England, in 1872, see *Journal of the Society of Arts*, xx., 252. These experiments show advantages in favor of the roller-gins. S. W. (in part).

COTTON-PRESS. See PRESS.

COTTON-SPINNING MACHINERY. Under this heading are grouped the machines which convert raw cotton into yarn ready for weaving, namely: I. Openers; II. Eveners and lappers; III. Carding-machines; IV. Drawing-frames; V. Mules and other spinning machines; VI. Spoolers; VII. Warping apparatus; VIII. Dressing apparatus. These will be successively considered.

Of late years the processes of cotton manufacture have been materially changed in some respects, and especially in the means used for opening the cotton from the bale and preparing it for the card. The old "willow" is now entirely superseded in the best mills by the improved "opener," which delivers the cotton taken from the bale in a tightly-wound "lap," instead of in loose light masses, which were liable to take fire if there was any gritty or gravelly matter among the cotton, as is often the case. Such fires are very troublesome to extinguish if once ignited.

I. THE OPENER confines the cotton in an iron casing until it emerges in the sheet to be wound up

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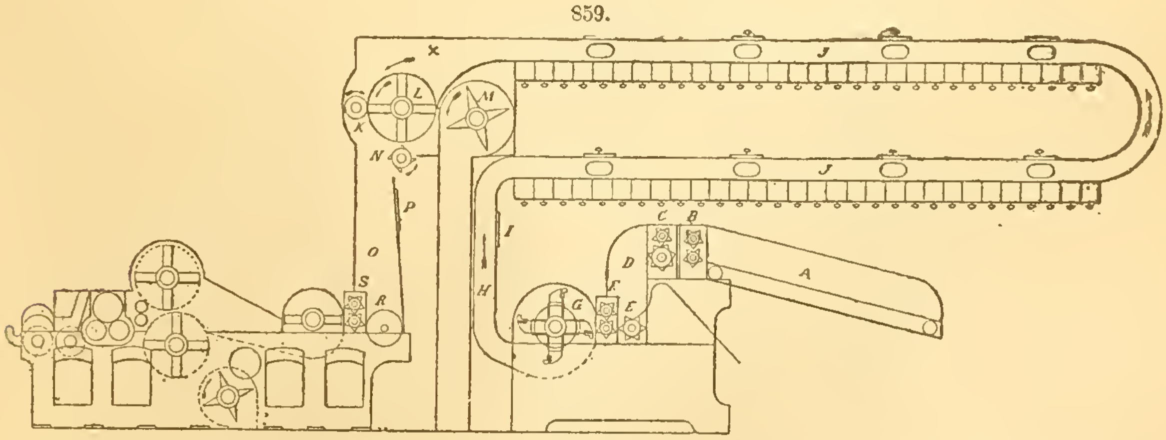
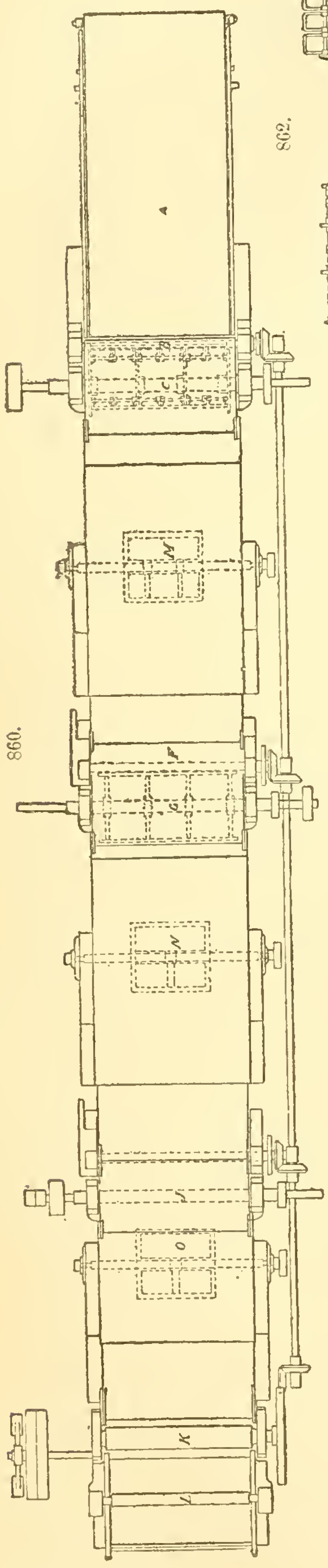


into a lap, ready to be transferred to the second machine, or lapper, where three of the opener laps are usually drawn down in thickness, and united in one, which in its turn is taken to the card. Two things are required to be accomplished by these machines: first, the thorough opening and loosening of the matted cotton as taken from the bales; and second, the removal of sand, stones, and seed, left by the gin, which are always found to a greater or less extent in the cotton as put up for market.

Fig. 859 represents an improved opener, built by the Kitson Machine Company of Lowell, Mass.,



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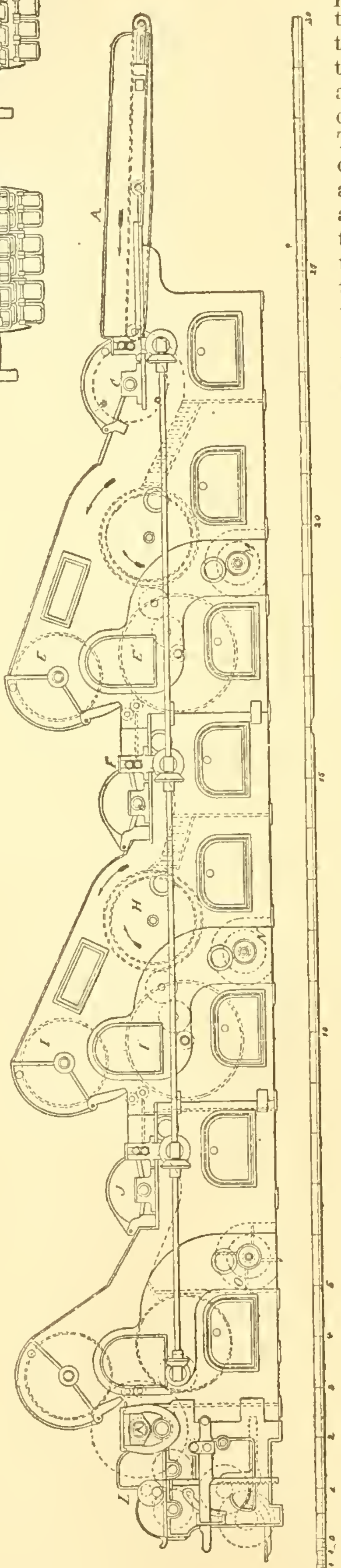

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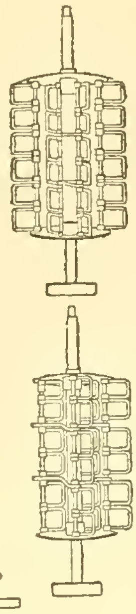

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and used in some of the principal cotton mills of this country. The feed-table or endless apron *A* receives the cotton and carries it to the feed-rolls *B*. The rolls *C* are the pulling or preparing rolls, and run twenty times faster than the rolls *B*; they consequently pull the matted bunches of cotton apart, and drop them in a softened condition into the gauge-box *D*. The rolls *F* and *E* receive this cotton from the gauge-box *D* in a sheet of uniform thickness, and carry it to the beater *G* in the opener. By the force of this beater it is blown through the circles *H* and trunks *J* to the condenser *X*, connected with which is the exhaust-fan *M*, which carries off the dust, and aids in pulling the cotton through the trunk. The entire bottom of the trunk *J* is made of hoop-iron slats standing edgewise a short distance apart, and the cotton, after being well opened by the preparing-rolls *C* and beater *G*, and blown over this sieve-like arrangement, is thoroughly cleaned. The roll *K* and the screen *L* in the condenser *X* slightly compress the cotton as it passes between them and drops into the gauge-box *O*. The ratchet-roll *N* acts as a clearer for the screen *L*, and at the same time throws out the surplus cotton if the gauge-box becomes too full. *P* is a glass door by which the operator can see the height of cotton in the gauge-box. The construction of this gauge-box and its connection with the rolls *S* and screen *R* are such that the cotton is measured in one uniform sheet to the lapper or scutcher, through which it passes and comes out in the form of an even lap, ready for the finisher-lapper or card. It is claimed for this trunk arrangement of machines that the cotton is cleaned in a more thorough manner than by the old process; that it will not clog in passing through, neither is there danger from fire; that the cotton is measured off by the gauge-box evener than it can be spread by hand, thus insuring an evener lap; and that the trunk, taking out the greater bulk of sand and grit before it reaches the lapper, saves the wear and tear of the same. This machine will open and clean 4,000 lbs. of cotton per day, with an expenditure of about 8 horse-power.

Another form of cotton-open-

er and picker, as built by Messrs. Whitehead & Atherton of Lowell, Mass., is represented in Figs. 860, 861, and 862. The cotton as taken from the bale is spread loosely on the feed-apron *A*, which delivers it to the feed-rolls *B*, from which it is taken by the hinged beater or whipper *C*, the details of which are shown in the smaller drawings on the right, Fig. 862, in which are exhibited the beaters which strike the cotton, and which are rectangular loops of best Norway iron hanging on rods, which are supported by the arms. The whole is driven by a belt-pulley, and the rapid motion causes the whippers to assume a radial position, as represented in Fig. 862, and strike the cotton from the feed-rolls, with a blow which is sufficient to remove the seeds and dirt, which fall through the gratings shown in the elevation, while the cotton is carried on to the wire-gauze cylinders *E E′*, from which the air is exhausted by the fan *M*. Passing through between these gauze cylinders, the cotton goes to another pair of feed-rollers *F*, from which it is again taken by the beater *G*, and carried on as before to the gauze cylinders *I* and *I′*, the air from which is exhausted by the fan *N*. The beater *J* again throws the cotton forward to a third pair of gauze cylinders, exhausted by the fan *O*, and from these it passes through the condensing-rollers *K*, and is wound up in a lap or sheet at *L*. The leaf-extractors *D* and *H* are large cylinders fitted with buckets like those of an overshot wheel on their periphery, and revolving slowly in a reverse direction to that of the cotton, as shown by the arrow. The cotton is thrown by the beater against the edges of these buckets, and much light material which has not fallen through the "grids" or gratings is caught in them, and dropped in their revolution into the dust-box under the machine.

The peculiar merit and novelty of this machine, which is now very extensively used, lies in the hinged or flexible beater, which, while delivering an effectual blow on all the cotton which is fairly loose, will yield to a hard mat or cake, such as is often found in heavily-pressed cotton, until the successive rapid blows have so loosened it as to permit its easy separation, thus avoiding much of the jar and wear to the machine incident in the use of the rigid beater, and also saving power. These machines, as represented in the cuts, have been found by actual test to open and clean 4,000 to 5,000 lbs. of cotton per day, with an expenditure of less than 2 horse-power per 1,000 lbs.

The lap which is taken from these machines now passes to the second picker or lapper, when three laps are united and drawn down into one, which is taken to the card. This operation is intended to secure evenness in the thickness of the sheet delivered to the card, and this object is also aided by the improved "evener," as illustrated and described below.

II. Eveners and Lappers.—The object of an evener, applied to a finisher-lapper, is to regulate the supply of cotton which passes through the machine so that laps of any required weight can be obtained, without being compelled to weigh the cotton on to the feed-apron of the breaker-lapper. To accomplish this result, a number of different kinds of eveners have been invented, many of which have been open to the serious and fatal objection of not being sensitive enough to produce an even weight of laps, in consequence of the construction of the evener being such that the feed-rolls were obliged to serve the double purpose of holding the cotton while being operated upon by the beater (necessitating a great weight upon the feed-rolls to hold the cotton) and to even the supply of the same passing through the machine.

The construction of the Whitehead & Atherton evener, represented in Figs. 863 to 865, is such that its only office is to regulate the supply of cotton, while the feed-rolls have no direct connection with the evener to interfere with its sensitiveness. In Figs. 863, 864, *PP* are two feed-rolls for holding the cotton while being acted upon by the beater. *T T* are two of eight evener-plates, between which and the roll *V* the cotton passes to the feed-rolls. These plates are connected by means of rods *R R* to the levers in the box *S*, which are connected with the lever *G*, attached to the shipper-lever *J*, which operates the quadrant belt-shippers *L L*. During the passage of the cotton over the evener-plates, should an uneven surface present itself, the plates immediately under the part that is uneven operate, and either increase or reduce the supply of the cotton to the beater, as is required to produce a given weight of lap. The cotton, being delivered as evenly as possible in this manner to the lapper, passes through two more beaters, which complete the cleaning and prepare it for the next operation.

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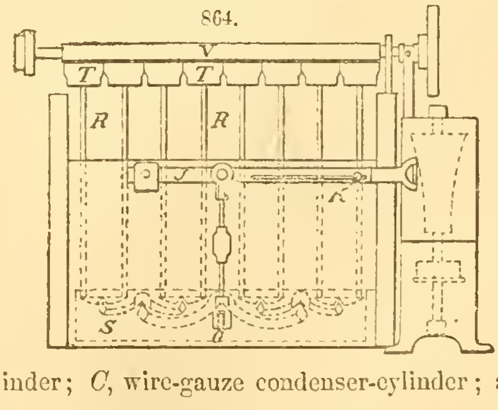
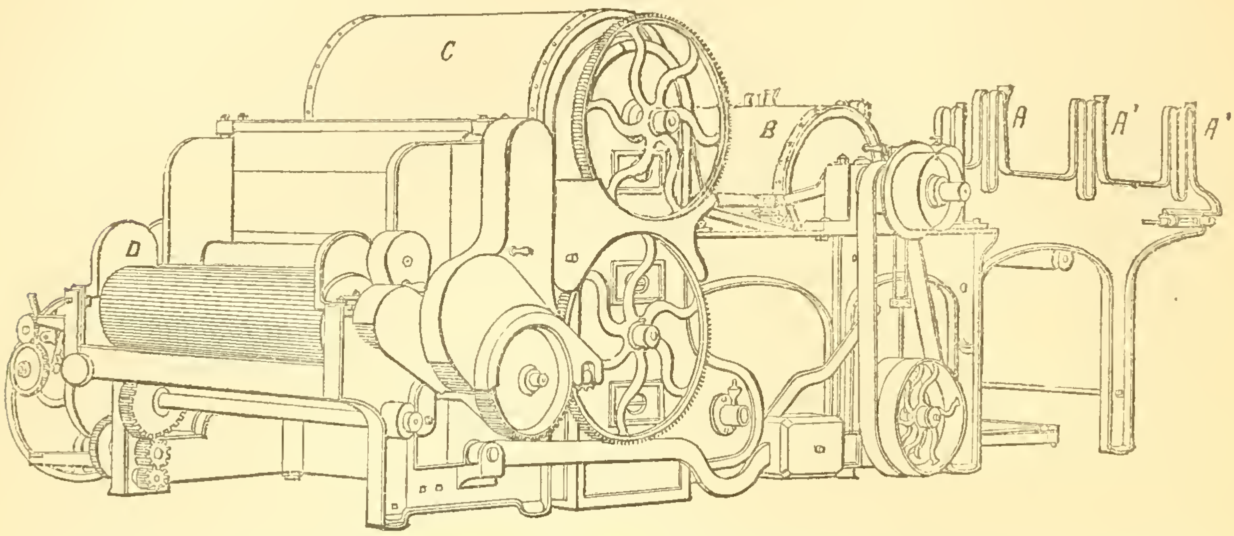


Fig. 865 is a perspective view of the finisher-lapper. At *A*, $A^1$, $A^2$ are the rests for laps from the opener. *B* is the beater-cylinder; *C*, wire-gauze condenser-cylinder; and *D*, the fluted roll for joining the laps.

III. Carding Machines.—From the apparatus thus far described the cotton emerges in the form of

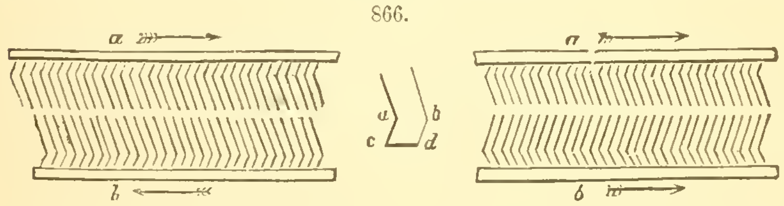
a very clean, light, downy fleece called a lap, consisting of short fibres thoroughly disentangled. But these fibres are not *parallel;* they lie across each other at every imaginable angle, and any attempt to combine them together in this state would be fruitless; they must be rendered parallel,

865.




and to effect this is the object of *carding.* This is an important process, as regularity and perfection in carding are essential to the fineness and beauty of the cloth. Cards are formed of strips of leather, in which are inserted small staples of wire called teeth, having the projecting ends slightly bent in one direction. The strips of leather are fastened to flat surfaces or cylinders of wood or metal, and the cotton is passed between two or more of these surfaces. The teeth of cards are of various sizes, being thicker or slenderer to adapt them to coarse or fine materials. It is essential that the teeth should be all alike, equally distributed, and equally inclined over the surface of the leather. The teeth are implanted by pairs, and retained in it by the cross part *c d*, Fig. 866, at right angles with the teeth. The leather must therefore be pierced with twin holes at the distance *c d*, and in such a manner that the slope of the holes in reference to the plane of the leather be invariably the same; for otherwise, the teeth would vary with the angle of inclination, and the card would be irregular. The leather should be of the same thickness throughout, so that all the teeth may project an equal distance. Card-making requires a degree of precision which is hardly possible with hand work, and cards are now manufactured exclusively by machinery.

866.




Strict uniformity is necessary as to the size, shape, obliquity, and length of the teeth, and also in the angle which they bear to the cylindrical surface around which they are placed. The action of the cards will be understood from Fig. 866. If the two cards *a* and *b* on the left be moved in opposite directions, as indicated by the arrows, with a tangled tuft of cotton-wool between them, the fibres will be seized by all the teeth, one card pulling them one way and the other pulling them in the opposite direction. The fibres are thus disentangled and laid in parallel lines, each card taking up and retaining a portion of the cotton. All the cotton may be gathered on one card by reversing the position of the two, and placing them as shown on the right of Fig. 866. Then, by drawing the upper card *a* over the lower one *b*, the teeth of the latter offer no resistance, but give up their cotton to the upper card.

The following is a description of the card-making machine invented by Mr. Whittemore. Long sheets or fillets of leather, of suitable length, breadth, and thickness for making cards, are stretched by winding the fillets upon a roller or drum, from which it is conducted upward between guide-rollers to a receiving-roller at the top of the machine, where it is held by a cramp, by which means the leather is kept stretched.

The holes are pierced in the leather to receive the wire staples or teeth of the card by means of a sliding fork, the points of which are presented to the face of the leather, while the fork is made to advance and recede continually by the agency of levers, operated by rotatory cams upon a revolving main shaft. The leather fillet is shifted so as to bring different parts of its surface opposite to the points of the sliding fork, so that the holes shall be pierced at regular distances. This is done by cams, which shift the guide-rollers and confining-drums laterally as they revolve, and consequently move the fillet of leather at intervals to the distance required between the holes.

The wire of which the teeth of the card are made is fed from a coil on one side of the machine, and brought forward at intervals by a pair of sliding pincers, moving to and fro through the agency of levers, operated by rotatory cams upon the main shaft. The pincers having advanced a distance equal to the length of wire intended to form one staple or two points, this length of wire is pressed upon exactly in the middle by a square piece of steel, and being there confined, a cutter is brought forward which cuts it off from that part of the wire held in the pincers. The length of wire thus

separated and confined is now, by a movement of the machine, bent up along the sides of the square steel holder, and shaped to three edges of the square, that is, formed into a staple; and in the same way the wire is cut and bent into staples as long as the machine is in operation.

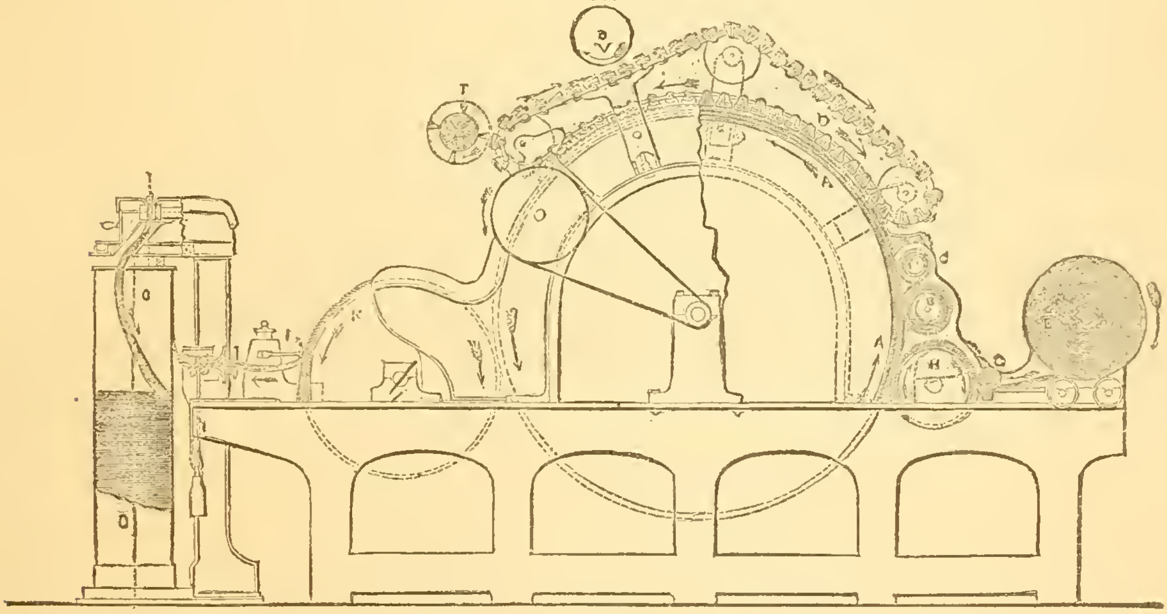
The wire staple is held with its points or ends outward in close proximity to the forked piercer before described, and by another movement the staple is moved forward, its points entering the two holes previously made in the leather by the sliding fork.

While the wire staple is being thus introduced into the leather, its legs or points are to be bent, that is, formed with a knee or angle. This is done by a bar or bed, which bears up against the under side of the wire staple when it has been passed half way into the holes in the leather, and another bar above it, being brought down behind the staple, bends it over the resisting bar to the angle required, forming the knee in each leg. A pusher now acts behind the staple, and drives it home into the leather, which completes the operation.

In this manner a sheet of card, sometimes called card-clothing, is made, of the kind usually employed for carding wool, cotton, or other fibrous materials. The wire staples are set in the leather, sometimes in lines crossing the sheets, which is called ribbed, or in oblique lines, called twilled, which variations are produced by the positions of the notches or steps on the periphery of the cam or indented wheel, which shifts the guide-rollers that hold the leather fillet as described.

The carding engine consists of one or more cylinders, covered with card leather or clothing, and a set of plane surfaces similarly covered, made to work against each other, but so that their points do not come into absolute contact. The action of the machine is substantially similar to that of the old hand-cards, which were simply wire brushes drawn past each other by hand in the manner already described. For making coarse yarns one carding process only is employed; but for finer yarns the cotton is first passed through a breaker carding engine, which performs the first rough carding; and the slivers delivered by this are then doubled by laying together a large number of them side by side and overlapping one another, so as to obtain sufficient thickness and breadth of material to allow of

867.



a further carding. The lap thus formed is fed into a second or finisher carding engine. As many as 96 slivers from a breaker card, each drawn out of a separate can, are laid together by a doubling machine into a single thickness for the supply of the finisher, in order that the mixing of the cotton may be more thoroughly effected, and more perfect uniformity insured in the sliver delivered by the finisher. For the finest qualities of yarn the finisher card is itself used as a breaker, and the sliver delivered by it is afterward combed by a combing machine. Fig. 867 shows the general arrangement of the mechanism of a carding engine such as is used as a finisher. The lap *E*, formed of a number of slivers, in this case from the breaker card, laid together into a fleece by the doubling machine, is carried by the feed-roller *G* to the *licker-in H*. The latter draws the cotton into the machine, so that its filaments are immediately seized by the large cylinder *A*, which generally rotates at a much higher speed than the drum *H*. The cotton is then teased out by the teeth of a "fancy roller," *B*, which runs in the same direction as the main cylinder. Its teeth, however, are bent forward in the direction of motion, and it therefore requires to be driven at a higher velocity than the carding cylinder, and has accordingly a surface speed of 2,000 feet per minute, that of the main cylinder being about 1,600 feet. The cotton is thus taken from the teeth of the main cylinder and thrown against those of the stripper *C*. The fibres, having thus been subjected to a preliminary carding, are again swept off the teeth of the stripper, moving at only 400 feet per minute, by the higher speed of the main carding cylinder. In some machines more rollers and strippers are added, so that knots taken out by the first drums and returned to the cylinder are again caught by others. Passing the combination of rollers, the fibres are next brought into contact with the cards of the top flats *D*, which arrest knots and hold them until the entanglement is removed, or until the flat is taken out and cleaned, which is occasionally done. The teeth of these flats are set to face those of the carding cylinder *A*, and travel forward in the same direction as the surface of the cylinder, but at a very slow rate. The flats are arranged to work at a slight inclination to the surface of the card-

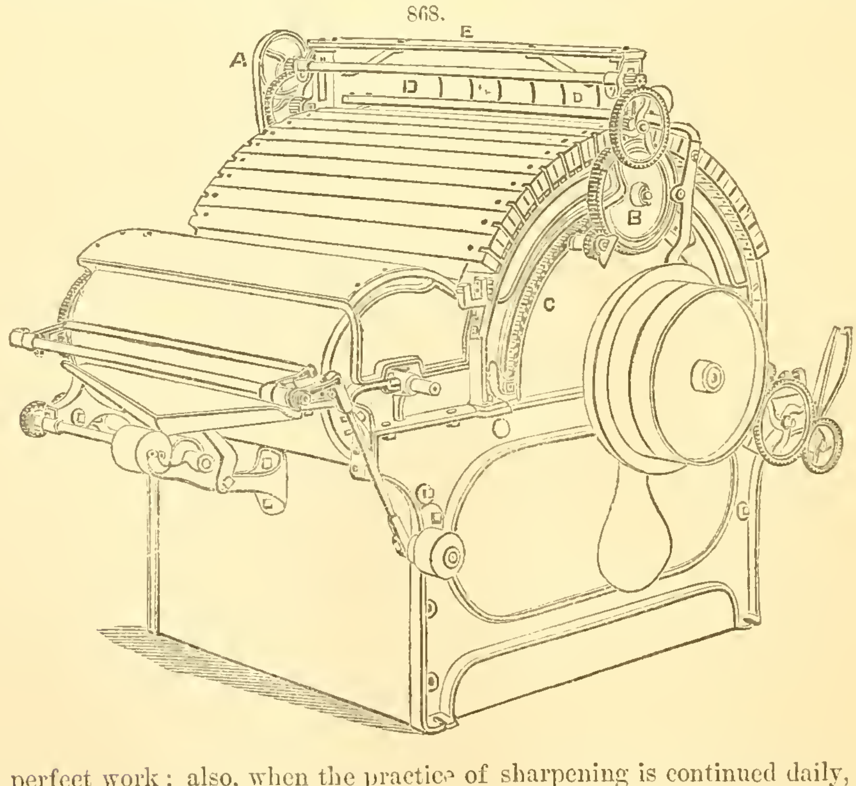
ing cylinder, so that the delivering side of each flat is closer to the cylinder, and a wider space is left at the entering side between the flat and the cylinder for the cotton to enter. The angle thus formed is called the bevel of the flat. On quitting the carding cylinder each flat in turn is stripped of any impurities by a vibrating comb. The flats are further cleaned by the brush *I*, and their surface is kept true by an emery-wheel, *V*.

The fleece of straightened fibres, which now lie in parallel rows among the teeth of the cylinder card, is removed by the doffer *K*, which is covered by a spiral fillet of cards revolving at a much slower rate than the cylinder, and in a different direction. From the doffer the fleece is removed by a vertically reciprocating comb *J*, called the *doffer-knife*, which has a rapid motion tangential to the surface of the teeth. The material is then contracted into a sliver by condensing rollers, which, revolving at a relatively greater velocity as the sliver proceeds, slightly draw it, and tend to make the fibres parallel. Thence the sliver is coiled down in the can *O*. The coiler consists of a revolving plate having an eccentric aperture, through which the sliver is passed from a pair of rollers above the plate. The can is also made to revolve with a slow motion in the opposite direction to the coiler, and the centre line of the latter is eccentric to the axis of the can, whereby the sliver delivered from the coiler describes a succession of curves in the can, which form coils continually crossing each other, so that when the sliver is removed its parts do not adhere together.

The breaker carding machine differs from that above described in having a series of pairs of carding rollers or workers and clearing rollers or strippers, arranged around the entire upper surface of the main cylinder. In each pair of rollers the fibre undergoes combing out and straightening. The means for taking the cotton upon the main cylinder and delivering it in coils are similar to those already detailed. Carding machines are sometimes made which are a combination of the breaker and finisher card, having rollers and clearers on the side of the cylinder next the feeder, and flats on the side next the doffer. The finisher carding machine was formerly constructed without the licker-in, the main cylinder taking the fleece directly from the feeding roller. This caused the fibres to clog the cards.

For the purpose of *sharpening the teeth*, when a carding engine is first filled with new sheets, fillets, etc., the cylinders are put in motion the right way, and a light emery-board, about 4 inches broad, is traversed over the top of the cylinders with a very delicate hand; this is called facing up the teeth, because the points of the wires are running against the board, and is intended to cut down any single wires that may be too long. After running the cylinders in this way about 15 minutes, their motions are reversed, and they are mounted on the main and doffing cylinders; these are denominated the fast-grinders, and, after being properly set, are caused to revolve in an opposite direction to the card-cylinders. This operation is continued until the whole of the teeth on both cylinders are ground down to one uniform length; but, during the process of grinding, the emery cylinders are made to traverse a little each way, so as to grind the wires to a round point, and prevent them from being hooked. The cards are then dressed up—first with a brush dusted with chalk, and then with emery-boards, called strickles; this latter process is called sharpening, and is continued daily to the breakers, and every second day to the finishers. The fast-grinders are not applied above once a year, or only when the cylinders on some part of the surface have become higher than on the other parts, or, technically, "off the truth." By this method of grinding the cards when necessary, and sharpening them every working day, they are always in good order, and consequently

868.

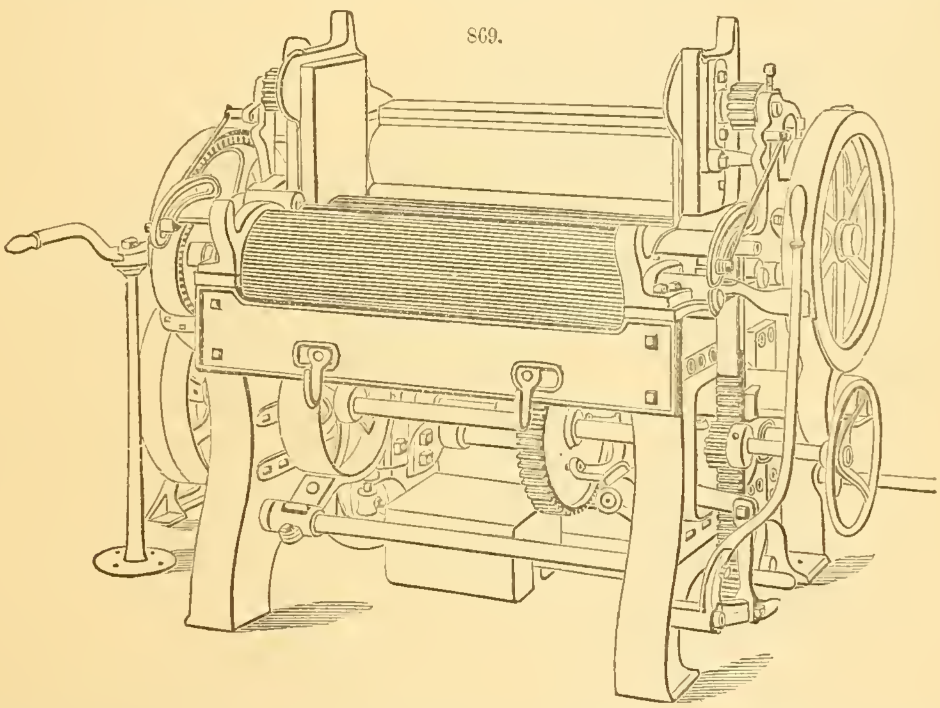



produce more perfect work: also, when the practice of sharpening is continued daily, it can be done in much less time; two men can easily sharpen 30 carding engines in the space of 4 hours. The card-belts being all fitted with buckles, no time is lost in making them long or short, for the purpose of reversing the motion of the cylinders. The tops are also brushed out and sharpened once a week.

Fig. 868 represents the carding engine ordinarily used in New England, as built by the Lowell Machine Shop, with Wellman & Woodman's improved self-stripper. The compound cam and mangle-wheel *B*, driven from the pulley *A*, traverses slowly from back to point of the card, and returns over its path by means of the semicircular mangle-rack *C*, stopping in its progress at each alternate top flat, which being raised from its seat by the spring bar *E*, driven from a cam on the opposite side of the card to the one shown in the drawing, the cleaner-comb *D* is passed under it, and on being drawn out removes the dirt and short cotton from the top flat, leaving it held by the curved wires shown in the drawing, until such a quantity has accumulated as to make it necessary to remove it by hand. This "stripper," which was introduced in 1856, has now become of universal use, not only saving a large amount of hand-labor, but also causing much less injury to the card-clothing than was caused by hand-stripping, from its even and steady motion. This motion is so arranged by cams as to strip the alternate flats, numbered 1, 3, 5, 7, etc., in its passage from back to front of the card, while on its return it cleans those numbered 2, 4, 6, 8, etc. By the form of the different cams and gears, the traverse motion of the stripper is arrested at each flat for the necessary length of time required to lift the flat, strip it, and return it to its seat before moving to the next one. The same form of card is used for both breakers and finishers, and the sliver of cotton is delivered from the doffer-comb into the "railway-box," a long box or trunk running the length of the section of cards immediately under the doffer, in which an endless belt, of leather or canvas coated with India-rubber, conveys the slivers from the section of cards in a parallel state to the railway or lap head, which is simply a set of rolls placed at the end of the section.

In the case of the breaker-railway or "lap-head," as it is called, Fig. 869, the slivers of a large number of cards, not often less than 64 or more than 96, are wound into a broad flat lap of the width

869.



of the finisher-card, to which they are transferred. This lap-head is shown in perspective in the engraving. The cards for this would usually be arranged in 4 or 6 sections of 16 each, according to the width of the mill, and placed longitudinally in the same; while at the end of each section a belt running transversely would receive the slivers from that section, uniting in one broad sheet at the lap-head, which would stand in line with the last section.

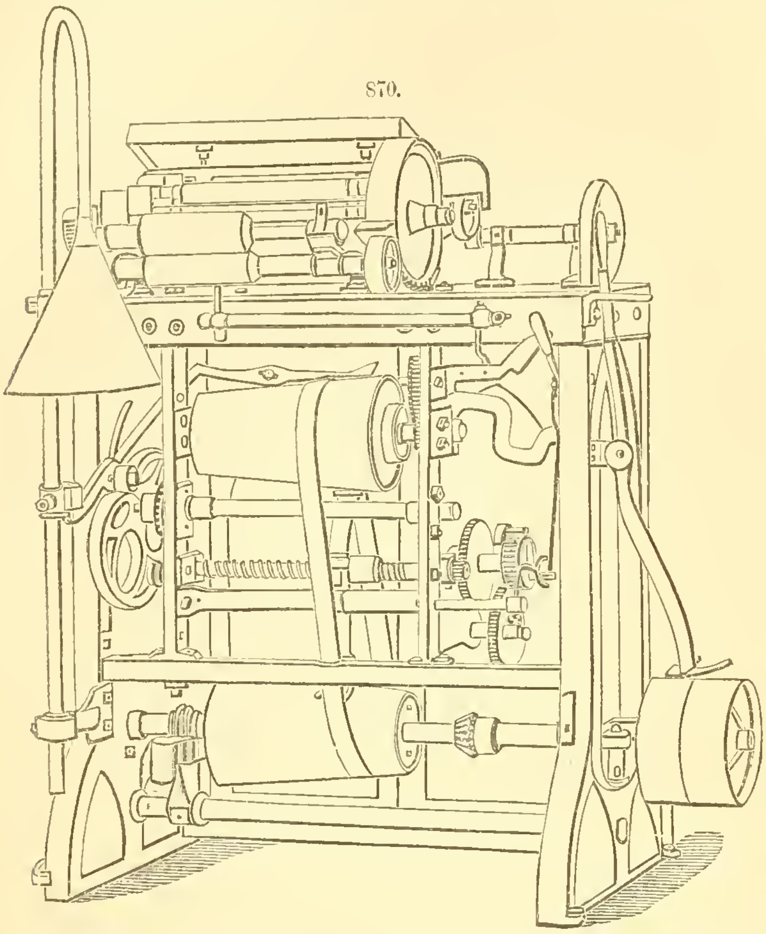
The section of finisher-cards is usually not less than 8 nor more than 16 cards, and the railway-head to the finishers consists of a set of drawing-rolls, as described in the "drawing-frame," usually with a draught of from 3 or 4 to 1. At this point the sliver is delivered into cans, which are carried to the drawing-frame. The number of cards in a section, and the draught of the railway-head, are regulated by the fabric to be produced, it not being considered advisable that the railway-sliver should weigh over 100 grains per yard. This sliver, on leaving the drawing-rolls, passes through a conical tube or "trumpet," accurately bored to a given size, which, by a system of levers acting on a belt in the interior of the machine, driven by one of a pair of conical drums or pulleys, so changes the speed of the front rolls that the sliver keeps its full size and weight when one of the cards is accidentally or intentionally stopped. This apparatus is known as "Hayden's railway evener and drawing regulator," Fig. 870. It is the invention of Newell Wyllis of Glastenbury, Conn., and D. W. Hayden of Providence, R. I., and has been improved by George Draper of Hopedale, Mass.

Still another form of card which has given successful results under practical test, invented and built by Messrs. Foss & Pevey of Lowell, Mass., is represented in Fig. 871. This, by using more flats, aims to produce the same result at one carding which formerly required two, thus saving one-half the room in the mill, and, as shown by the test annexed, one-third of the power and labor. The power required to drive cards varies with the amount of cotton carded per day, varying from one-sixth to one-third of a horse-power per card, including railway-heads, which respectively take about 1½ horse-power for the breaker lap-head, and one-half horse-power for the finisher-railway;

and the amount of cotton to produce the above results varies from 27 lbs. per day, single carding, to 60 lbs. per day, double carding.

The following gives the results of a power test of the Foss & Pevey under-flat cotton card, conducted at the Massachusetts Mill, Lowell, Mass., August 1, 1878: Eight top-flat breakers (old style) took 2.264 horse-power; eight top-flat finishers, with railway, 2.679; allowance for lap-heads, as by previous tests, .264. Sixteen top-flat cards, carding 520 lbs. cotton per day, took 5.207 horse-power; eight Foss & Pevey cards, including railway, carding 520 lbs. cotton per day, took 3.277; saving in power, 1.930, besides the saving in room and attendance, the quality and quantity of work being the same.

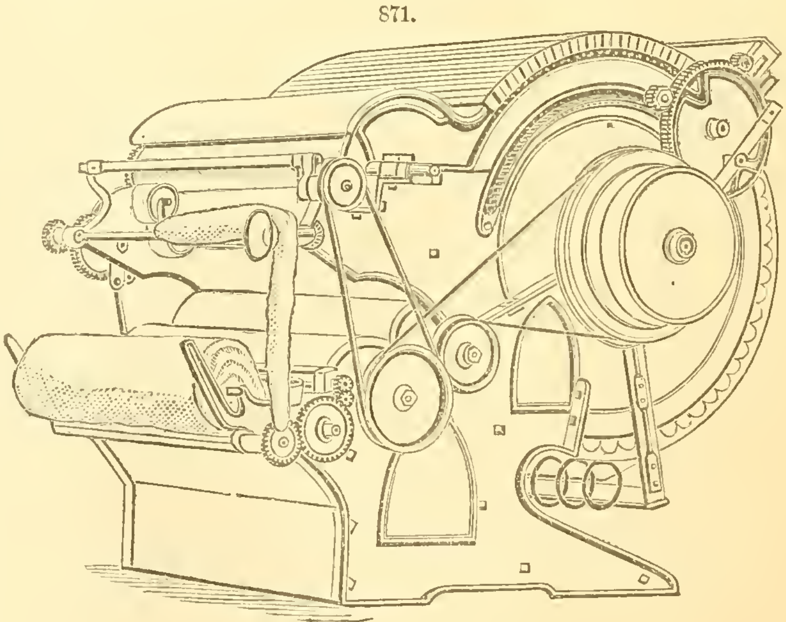
870.



The "top-flat" system of carding, as already described, is the one which has been generally adopted in the United States; but numerous important variations have been lately introduced, notably in the new combination card of the Whitin Machine Company, which adds the "worker and stripper," as used in wool cards, to a part of the top flats. In this case the cotton is taken from the feed-rolls by a licker-in, which delivers it to the main cylinder, and the flats, which it reaches first, collect the larger part of the leaf and shells before it reaches the workers, by which it is evenly distributed. This form of card is intended to work from 80 to 100 lbs. of cotton per day, or double the amount allowed to the flat card. A card is largely used in England, in which the positions of the parts are exactly reversed, the cotton being leveled by the workers and strippers before going to the top flats, which catch the dirt and waste.

Another form of English card is known as the roller card, and has no top flats at all, but uses the workers and strippers entirely. A card of this kind has been introduced in this country by the Messrs. Gambrill of Baltimore, and is known as the Gambrill card. One of these cards will turn out from 160 to 180 lbs. of cotton per day; it takes out less waste and cleans the cotton less thoroughly than the flat card, but is very serviceable with clean cotton or for coarse work.

871.

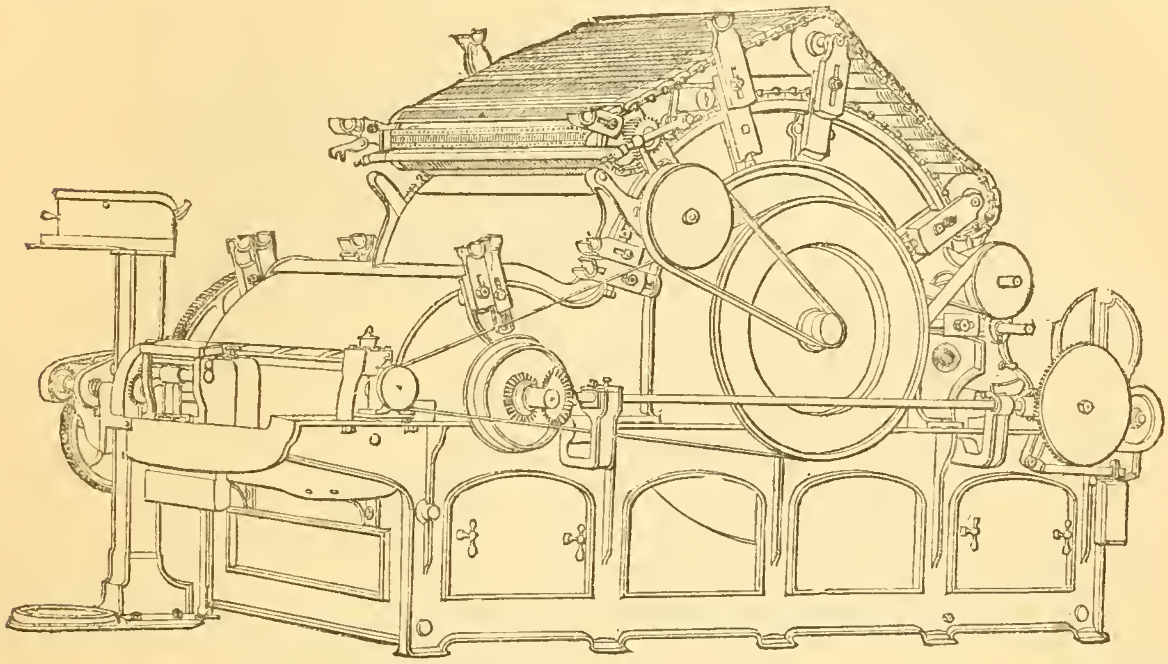


Still another form of English card is represented in Fig. 872, in which the top flats are attached to an endless chain, which travels slowly in the same direction as the surface of the main cylinder, and by the operation of which, as shown in the cut, each card-flat is reversed in position as it leaves the cylinder to return to the starting-point. It is then stripped by a cleaner-card, which is stationary at that place.

IV. Drawing-Frames.—The cotton leaves the carding engine in the state of a delicate, flat, narrow strip or ribbon, called a sliver; and these slivers have now to be converted into drawings by being elongated, narrowed, and thinned to a still more delicate condition. In the first place the slivers are collected in tall cans, from two to six in number, on one side of the "drawing-frame," and are from thence carried upward to two or more pairs of rollers, the two rollers of each pair revolving

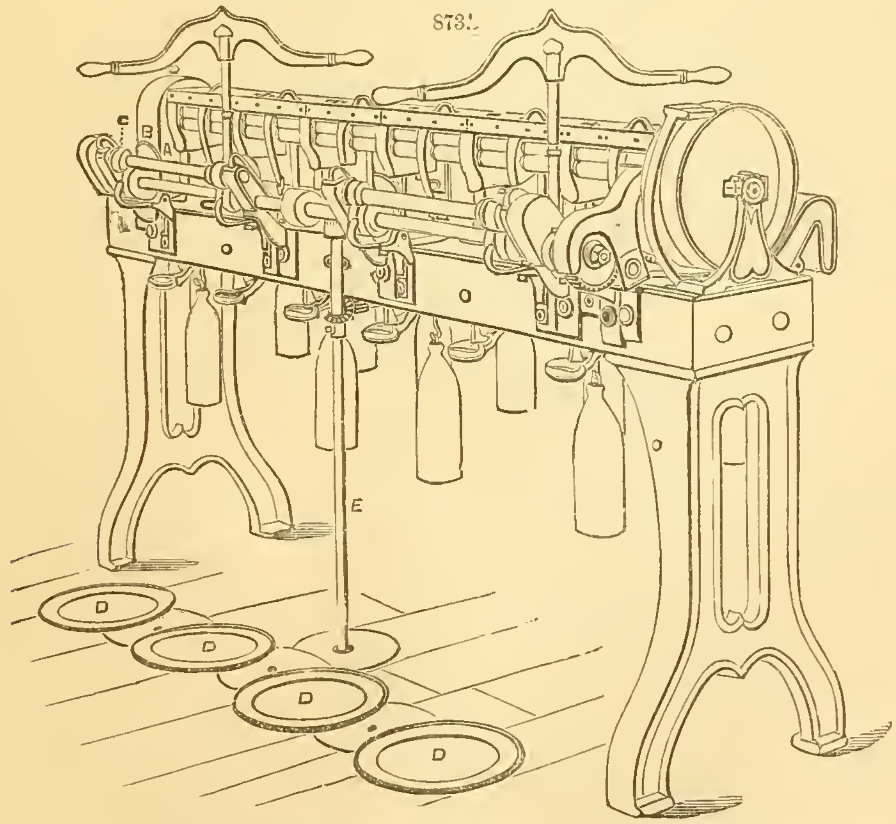
in contact. Here all the slivers or cardings are collected into one group, and are drawn between the rollers by the rotation of the latter. Now, if these rollers all revolved equally fast, the cotton would leave them with the same united thickness as when it entered; but the last pair revolve quicker than the first, so as to draw out the cotton into a more attenuated ribbon, because the more

872.



slowly revolving rollers do not supply the material fast enough for the maintenance of the original thickness. This is perhaps the most important principle in the whole range of the cotton manufacture; for it is exhibited alike in the present process and in the next two which follow. All the slivers are connected into one after leaving the rollers, and the united drawing passes through a kind of trumpet-shaped funnel, and thence is conducted into a tall can, round the interior of which it coils itself. One consequence of the drawing process, if properly conducted, is that the drawing is per-

873.

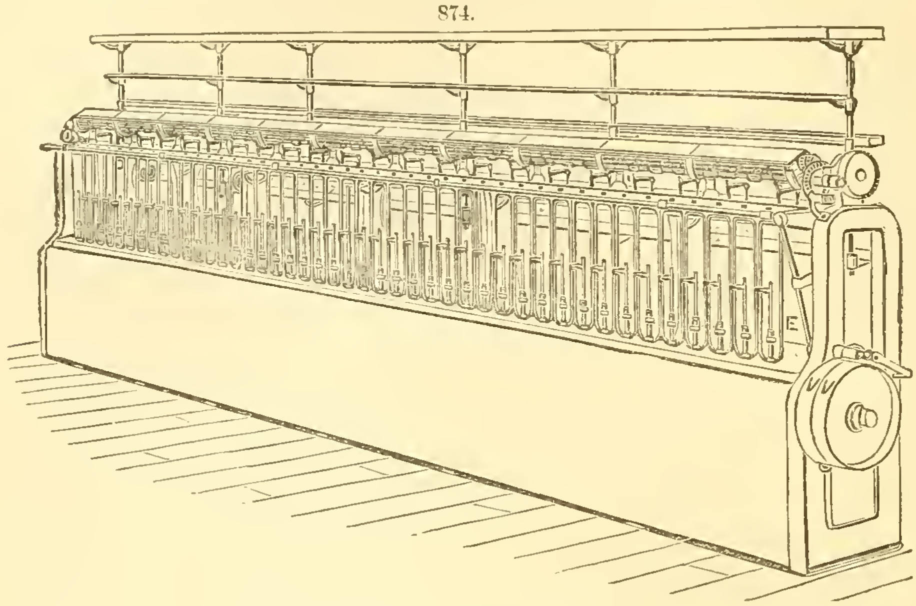


fectly equal in thickness in every part, and formed of parallel fibres; and in order to insure this, the drawing is repeated more than once, each narrow ribbon being "doubled" with others before each successive drawing.

The drawing-frame as built by the Lowell Machine Shop is represented in Fig. 873. The cans which have received the sliver from the railway-head, which is in reality a "first drawing," are placed behind the frame, and the attenuated sliver is delivered at the front through the rolls *A*.

Two or more of these slivers are united at the trumpet *B*, and compressed by the condenser-rolls *C*, and delivered again into cans which stand on the rotating plate *D D*, to which a reciprocating action from right to left and *vice versa* is given by the shaft *E*. The drawing-frame, as now usually built,

874.

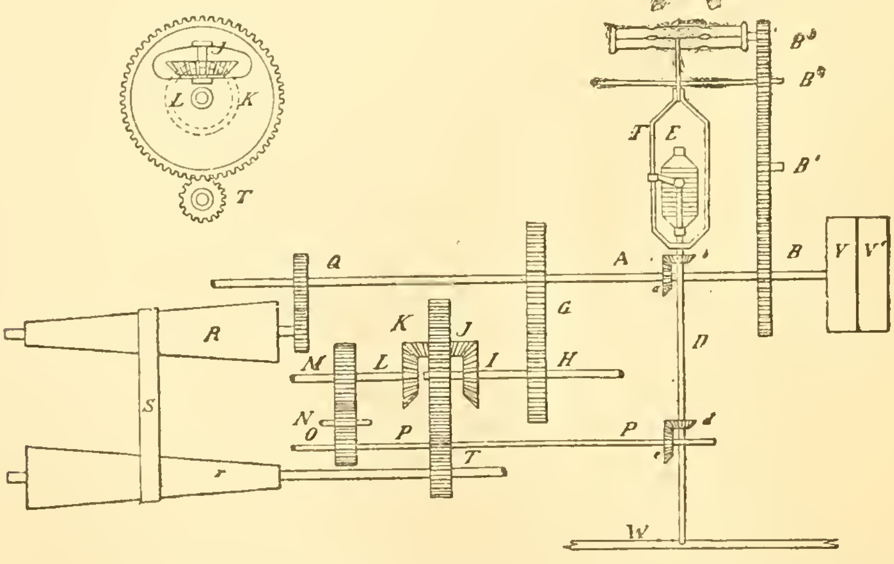


has 4 pairs of consecutive rolls, the speed of which varies according to the quantity and quality of the work desired. The draught or attenuation in the machine will vary, accordingly, from 3 to 4½ to 1, and the speed of the different rollers may be approximately stated as follows: first pair, 100 revolutions per minute; second pair, 125 revolutions; third pair, 130 revolutions; fourth pair, 300 revolutions. It will be seen by this that the draught is arranged to come between the first and second and the third and fourth pairs of rollers, the last being the greatest, and that between the second and third pairs barely sufficient to keep the fibres in tension. The average power of the drawing-frame may be taken at one-tenth horse-power for each delivery.

*Roving-Frames.*—Two sets of drawing-frames, known as first or second drawing, are usually employed, and from the second, Fig. 874, the sliver passes to the roving-frame, where it is brought to the state of *roving*. In many respects the process of roving is similar to that of drawing, inasmuch as it draws out the cotton to a state of still greater attenuation; but as the cotton, in its now reduced thickness, has scarcely cohesive strength enough to make the fibres hold together, the roving has a slight twist given to it, by which it is converted into a loose kind of thread, or spongy cord.

The "bobbin-and-fly frame" consists of a system of vertical spindles, on each of which is placed a reel or bobbin, and also a kind of fork called a "fly," still farther removed than the bobbin from the axis of the spindle. The drawing or delicate sliver of cotton is first drawn through or between rollers, and elongated to the state of a roving; then this roving passes down a tube in one prong of the fork or fly, and becomes twisted by the revolution of the fly round the bobbin, while at the same time the twisted roving becomes wound with great regularity upon the bobbin. The machine in fact performs three different and distinct operations: it first attenuates the "drawing" to a state

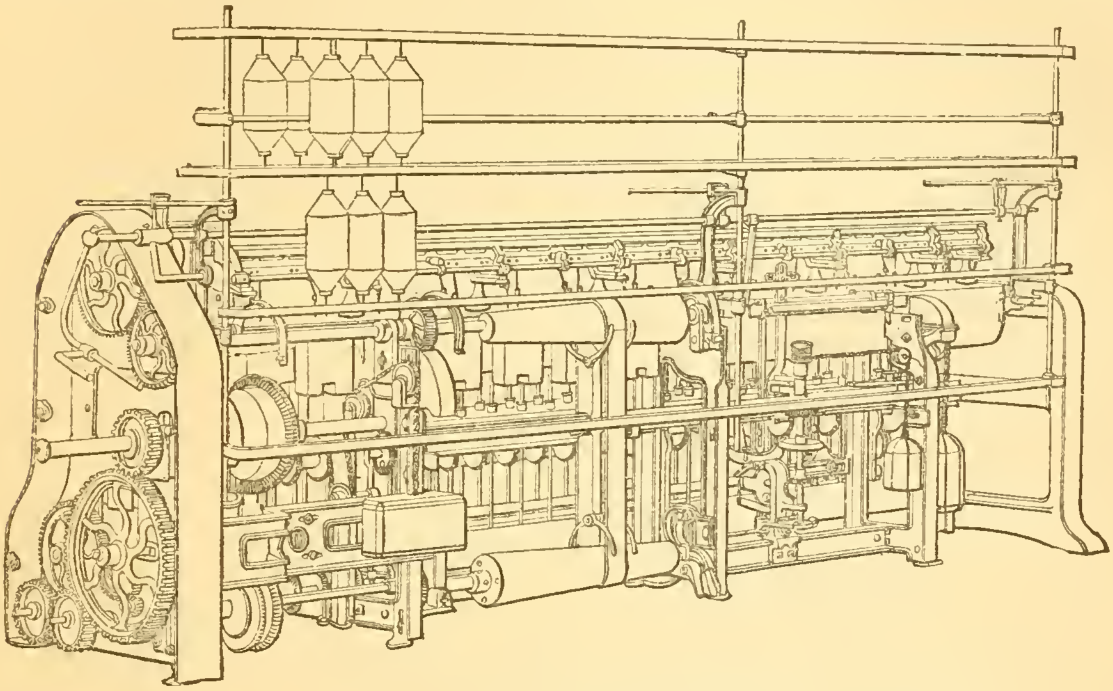
875.




of still greater thinness and delicacy than it had before; it then gives to the roving thus produced a slight twist, sufficient to enable the fibres to cohere; and, lastly, it winds this twisted roving upon a bobbin, on which it is conveniently transferred to the spinning machine. Instead of the bobbin-

and-fly frame, in this country the speeder and stretcher are more commonly used, especially on the coarse yarns. The principal difference in the two machines is that, while in the fly frame the flyer is like an inverted U, and is screwed to the top of the spindle, requiring to be unscrewed and replaced each time the bobbin is dropped, in the speeder it is in the form of a flattened ellipse, as shown in the engraving, and of double the length of the bobbin, thus permitting the removal of the latter without disturbing the flyer. From two to four of these machines are successively employed to reduce

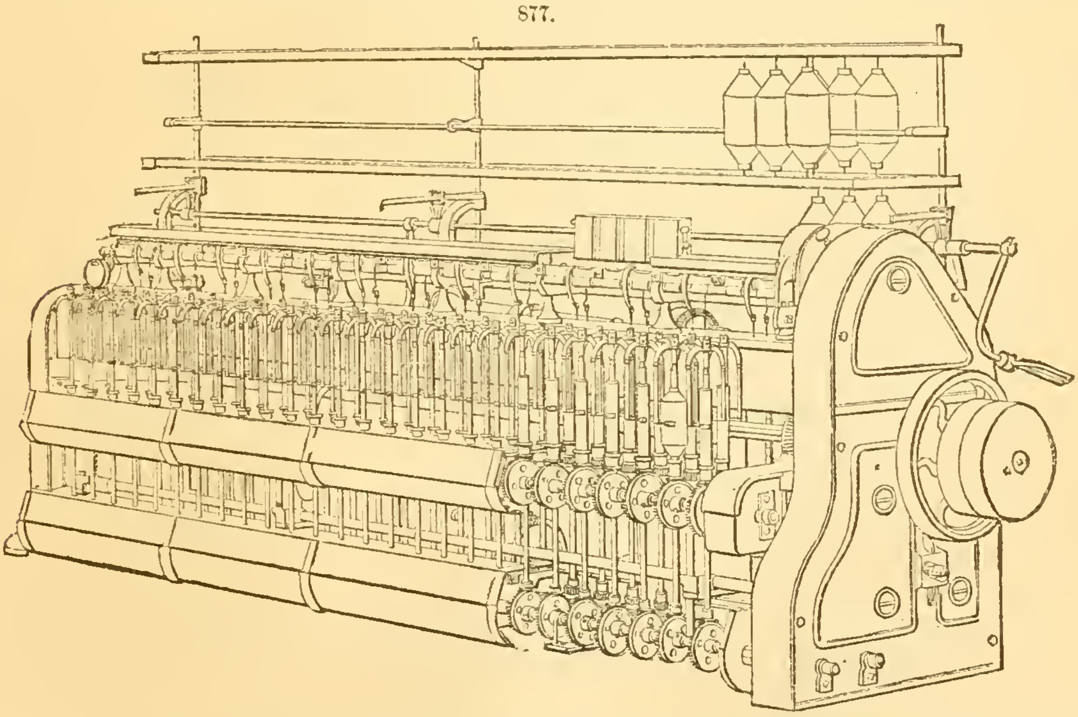
876.



the roving to the proper size for the yarn to be produced, doubling the roving to insure greater evenness before drawing at each operation.

The mechanism of the Lowell speeder, as generally adopted at present in the United States for

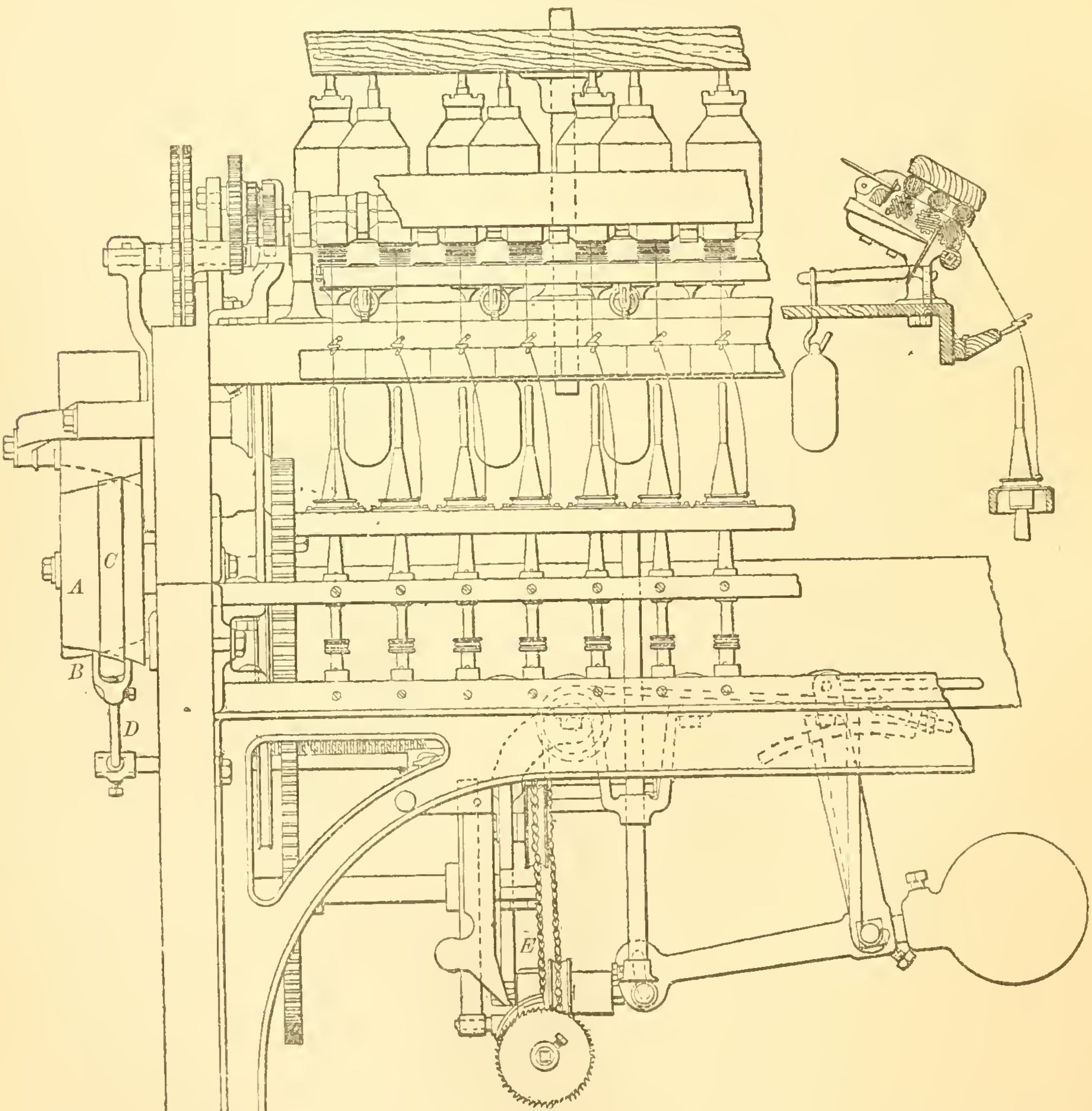
877.



coarse yarns, is essentially the same as that of the fly frame, its principal feature consisting of the "differential motion," so called, invented by Aza Arnold of Providence, R. I., in 1823, and introduced by Henry Houldsworth in England in 1825. By this motion the velocity of the surface of the bobbin, which is continually increasing in diameter with each successive layer of roving, is kept uniform, and takes up the roving exactly as fast as it is delivered by the presser or finger of the flyer. This differential motion may be briefly described as follows, by reference to Fig. 875: $A$ is the main or driving shaft of the machine, to which power is given through the pulleys $V\ V'$. The train of gears, $B$, $B^1$, $B^2$, etc., transmit motion to the drawing-rolls $C$, $C^1$, etc.; and the small bevels $a$ and $b$ carry the flyer $F$, which is always driven at the same speed, the amount of twist being regulated by the speed of the rolls $C$, $C^1$, which can be varied by changing the gears $B$, $B^1$, etc. These motions

are positive and uniform during the operation of the machine on any given size of roving. The roving, coming from the rolls $C$, passes downward through the hollow tube of the flyer to a presser, by means of which it is wound on the bobbin $E$. As this bobbin increases in size with every layer that is wound upon it, a variable motion must be given to it to keep the surface velocity the same, and thus avoid breaking the tender roving. This is accomplished as follows: A gear $G$ on the shaft $A$ drives the bevel-gear $I$ through the pinion $H$. $I$ communicates motion through $J$ to $L$, and thence through $M$, $N$, and $O$ to the shaft $P$, which, by means of the small bevels $c$ and $d$, drives the spindle $D$ and the bobbin $E$. Were the bevel-gear $J$ stationary, the motion transmitted would be the same as that received, only reversed in direction; but, in order to accomplish the desired result, it is given a motion around the centre of the shaft $H\,I$ by having its own axle inserted in the web of the large gear $K$, which moves freely on the shaft $H\,I$, and to which motion is given by the pinion $T$, which is driven from the shaft $H$ by the gears shown at $Q$ and the cone-pulleys $R$ and $r$, and the belt $S$. Now, if the gear $K$ be made to revolve around the shaft $H\,I$, carrying with it the fulcrum of the bevel $J$, it is obvious that the motion of the bevel $L$ and its consequent train of gears will either be advanced or retarded, according to the direction given to the gear $K$. In order to retard the revolutions of the bobbin in proportion to its constantly increasing diameter, the gear $K$ is therefore made to move in the same direction with the bevel $I$; and, as each successive layer of roving is put on to the bobbin, its velocity is increased by the shifting of the belt $S$ from left to right on the cone-pulleys $R\,r$ by a ratchet motion not shown here, but which is operated by the same action which lifts and lowers the bobbin for each successive layer. This is done by raising and lowering

878.
SIDE VIEW.




the rail $W$, in which the spindles are stepped, the spindles being splined, and sliding up and down through the driving-gear $d$. The exact proportions are not given in this drawing, the object being only to explain the motion, which is one of the most beautiful and important in its effects of any in the process of cotton-spinning.

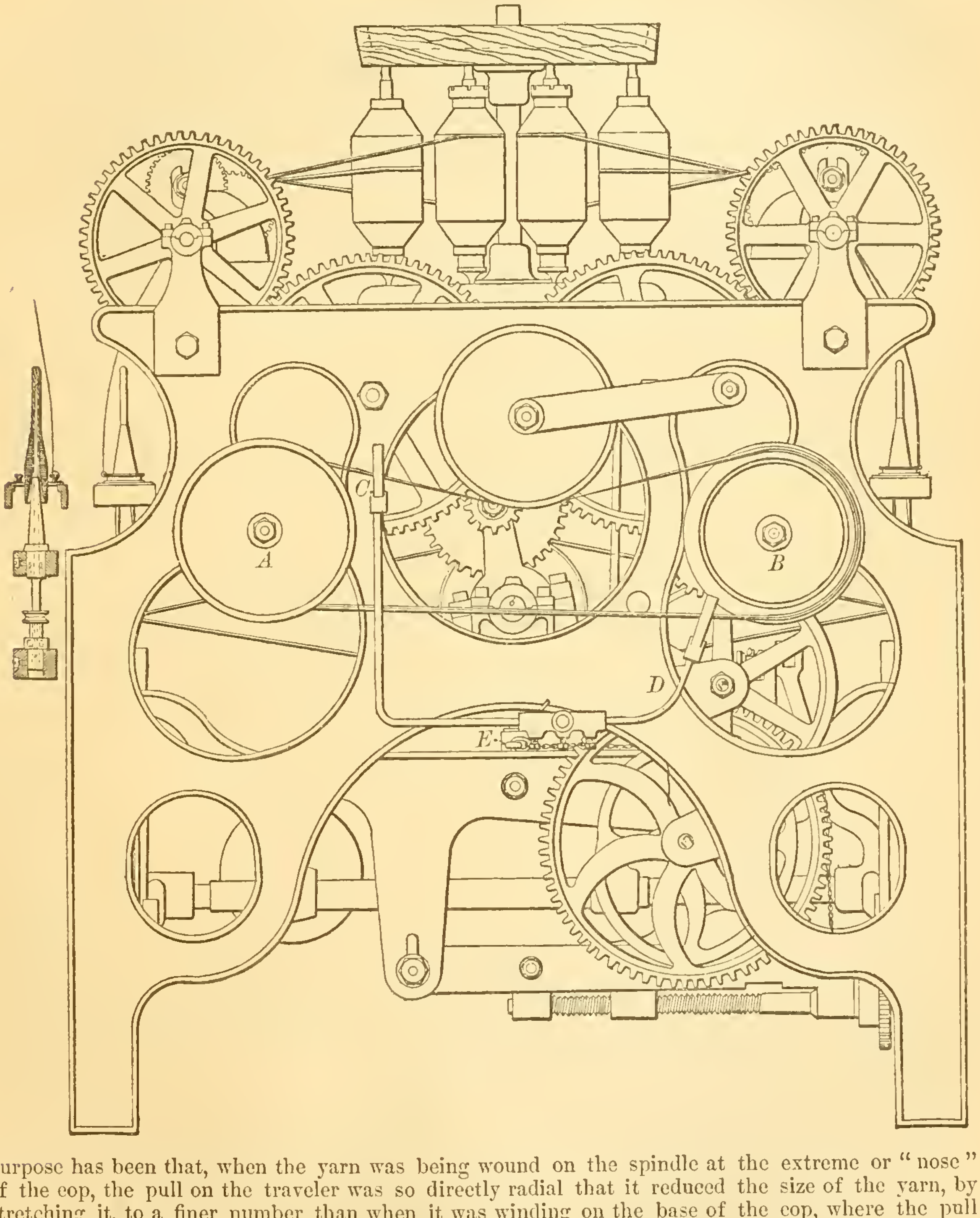
Fig. 876 is a rear view of the ordinary form of English roving-frame, exhibiting the general arrangement of the gearing; and Fig. 877 is a front view, showing the spindles and the gears by which

they are driven. These machines are built by nearly all the principal makers of cotton machinery in the United States, and are generally used for fine yarns.

Draper's filling-frame, Figs. 878 and 879, the invention of Messrs. George Draper & Sons of Hopedale, Mass., is designed to accomplish the object of spinning a soft-twist bobbin of weft, like the mule "cop," for use in the shuttle. The great difficulty in previous attempts to accomplish this

879.

END VIEW.

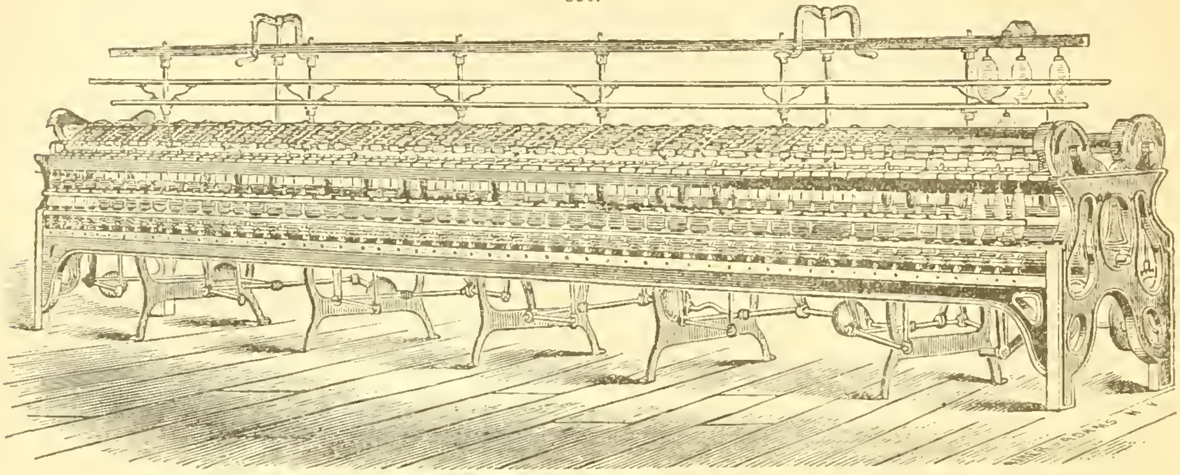



purpose has been that, when the yarn was being wound on the spindle at the extreme or "nose" of the cop, the pull on the traveler was so directly radial that it reduced the size of the yarn, by stretching it, to a finer number than when it was winding on the base of the cop, where the pull was more tangential. This objection the Messrs. Draper seek to obviate by diminishing the speed of the front rolls at the time the yarn is winding on the small barrel of the bobbin, so as to give less draught at that time, and consequently a coarser yarn is delivered from the rolls; but it is reduced to its proper size by the tension between the traveler and the bobbin. This is accomplished by the use of the cone-pulleys *A B*, by which the front rolls are driven independently of the others, and the driving-belt on which, *C*, is traversed from right to left by the shipper *D*, which in turn is moved by the chain *E*, connected with the lift motion, which gives the traverse to the ring-rail in such a manner that, when the rail is up at the top of the wind, the front rolls are receiving a slower motion than when it is down on the base of the cone. The drawings will fully explain all the details. This frame, though a very recent invention, is being widely introduced, as it produces a soft-twist weft, similar to that spun on the mule, with great rapidity, and occupies but one-half the floor space of the mule in a mill, while it can be tended by a cheaper class of operatives.

All previous attempts to spin weft in the frame directly upon the spindle without the use of a bobbin have proved failures eventually. The use of the bobbin also saves 50 per cent. of the waste.

*Spinning-Frames.*—The roving, having been reduced to the proper size for the intended number of

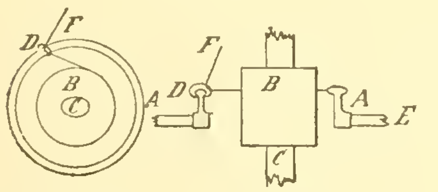
880.



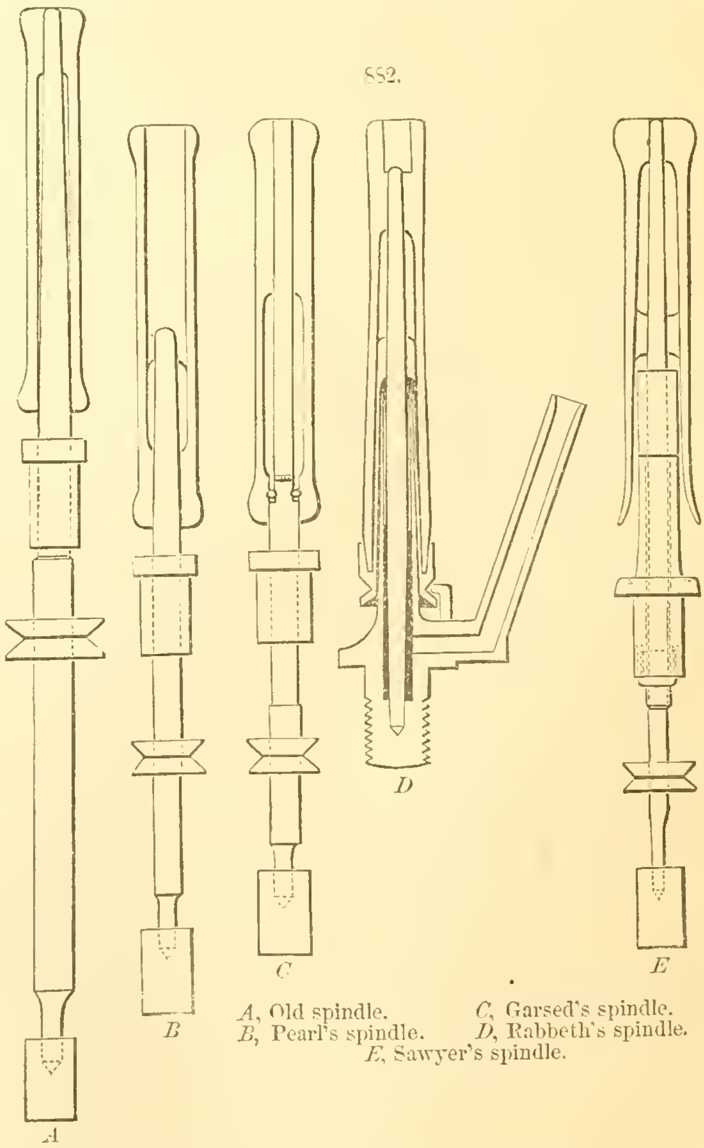
yarn, now goes to the spinning-machine, which may be a throstle or mule; the ring-throstle being generally used in the United States for warp, and the mule for weft, though either machine is occasionally employed for both purposes. Fig. 880 shows the ring spinning-frame of the latest pattern, as built by the Whitin Machine Company.

The principle of the ring spinning-frame is very simple. The spindle is driven by a band from a central cylinder, and the bobbin is held upon the spindle by a slight friction, and revolves with it,

881.




882.




*A*, Old spindle. *B*, Pearl's spindle. *C*, Garsed's spindle. *D*, Rabbeth's spindle. *E*, Sawyer's spindle.

the yarn being wound upon the bobbin by the friction of a "traveler" or small metal hook, which is carried by the yarn around a ring of hardened iron, which is concentric to the spindle, as in Fig. 881, where *A* represents the plan and section of the ring, *E* the ring-rail which carries it, and which rises and falls to give the traverse to the yarn on the bobbin *B*, which is carried by the spindle *C*, and gives the proper twist to the yarn. *D* is the traveler, which is carried by the thread *F*, and the resistance or "drag" of which winds the thread on the bobbin as fast as it is delivered by the spinning-rolls, the operation of which is identical with that of the rolls in the drawing and roving processes, being the fundamental principle as invented by Arkwright.

Great improvements have been made since 1870 in the construction of the spindles and bobbins. The first of these was the invention of Oliver Pearl of Lawrence, Mass., and consisted in cutting off 2½ inches from the top of the spindle, thus lessening the tendency to vibration, boring out the bobbin to a thin shell, and then strengthening it by reënforces, or bushings, at the bottom, top, and centre, the centre bushing being at the height of the top of the spindle, and by its adhesion thereto, combined with the adhesion of the bush at the bottom, getting friction enough to be carried around with the spindle. This reduction of weight above the bolster admitted of a much larger reduction

below, so that the weight of the spindle was reduced from 12 or 13 ounces to 5 or 6 ounces, and the bobbin from 1¼ ounce to half an ounce, saving one-third of the power required to drive the spinning in a mill, or one-sixth of the whole power required in the manufacture.

A reference to Fig. 882 will show the difference from the old form of spindle, and also the forms of the Sawyer spindle, which was patented by Jacob H. Sawyer of Lowell in 1871, the Garsed spindle, and the Rabbeth spindle.

In the Sawyer spindle the bolster, or upper bearing, is at the top of a tube, which reaches half-way up into the bobbin, the latter being chambered out to receive it, and supported on the spindle by two "bushes," or reënforces, one at the top of the bobbin, and one just above the tubular bolster. By this arrangement the centre of gravity of the full bobbin is brought down close to the fulcrum, and the vibration of spindle and bobbin lessened still further than by Pearl's patent, with a somewhat greater saving of power, the spindle being, as before, reduced to 5 or 6 ounces.

Another light spindle was introduced by Richard Garsed of Frankford, Philadelphia, in 1872, in which the bobbin is chambered out for half its height from the bottom, or nearly to the top of the spindle, and a reënforce inserted at the bottom, two steel wires passing through, forming a clutch, which engages on a squared shoulder on the spindle, just above the bolster, and driving the bobbin by a positive motion, the pit of the bobbin at the top of the spindle not being tight enough to cause friction.

Still another form, introduced in 1871–'72, is the "Rabbeth" spindle, built by Fales & Jenks of Pawtucket, R. I., in which the bobbin is similar to that of the Sawyer, but in which the spindle runs in a tube full of oil, a sleeve carrying the driving-whorl, on its lower end, being so attached to the spindle as to overhang the tube, and with it be introduced into the lower half of the bobbin, which is partially supported and driven by it.

Many thousands of each of these forms of light spindle are now in operation, saving from 33 to 40 per cent. of the power formerly required, or admitting of being used at such increased velocity as materially to increase the product of a given number of spindles with the same power as before.

V. Mules.—In these machines the rovings are delivered from a series of sets of drawing-rollers to spindles placed upon a carriage, which travels away from the rollers while the thread is being twisted, and returns toward the rollers while the thread is being wound. The drawing and stretching action of the mule-spinner makes the yarn finer and of a more uniform tenuity than the mere drawing and twisting action of the throstle. As delivered by the rollers, the thread is thicker in some parts than in others; and the thicker portions, not being so well twisted, are softer and yield more readily to the stretching power of the mule, by which means the twist becomes more equable throughout the yarn. Throstle-spinning is seldom employed for numbers higher than 40 or 50 hanks to the pound, because smaller yarn would not have strength enough to bear the drag of the bobbin; but in mule-spinning the yarn is built upon the spindles without subjecting it to appreciable strain. The mule-carriage carrying the spindles recedes from the rollers with a velocity somewhat greater than the

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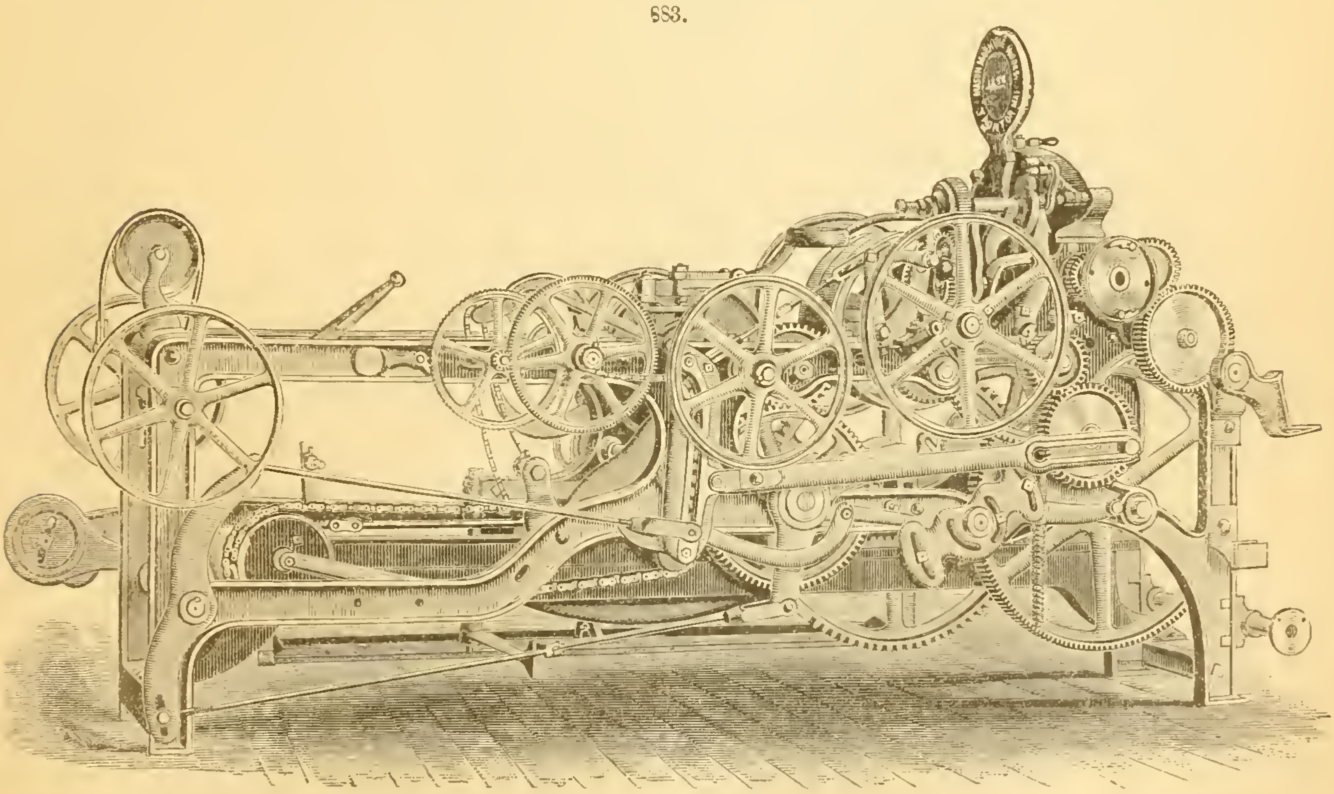
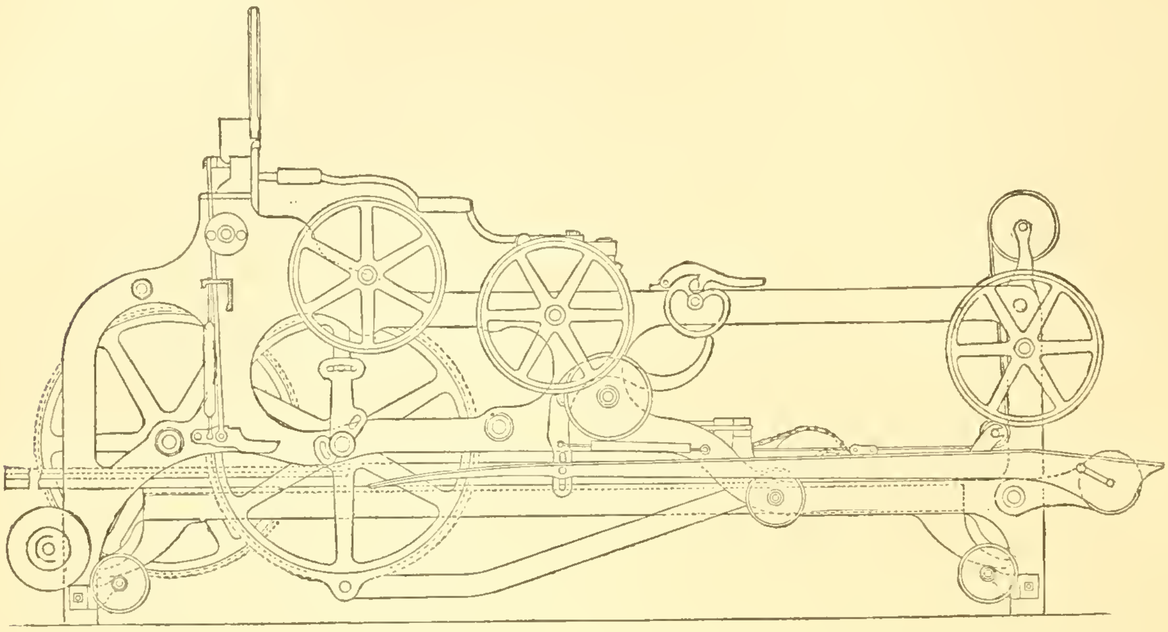


rate of delivery of the reduced roving, the rapid revolution of the spindles giving a twist to the yarn which stretches it further. When the rollers cease giving out the rovings, the mule-spinner still continues to recede, its spindles revolving, and thus the stretching is effected. The distance to which the spindles recede from the rollers while both are in action is called a *stretch*. This is usually from 54 to 56 inches. The space over which the carriage moves in excess of the paying out of the rollers

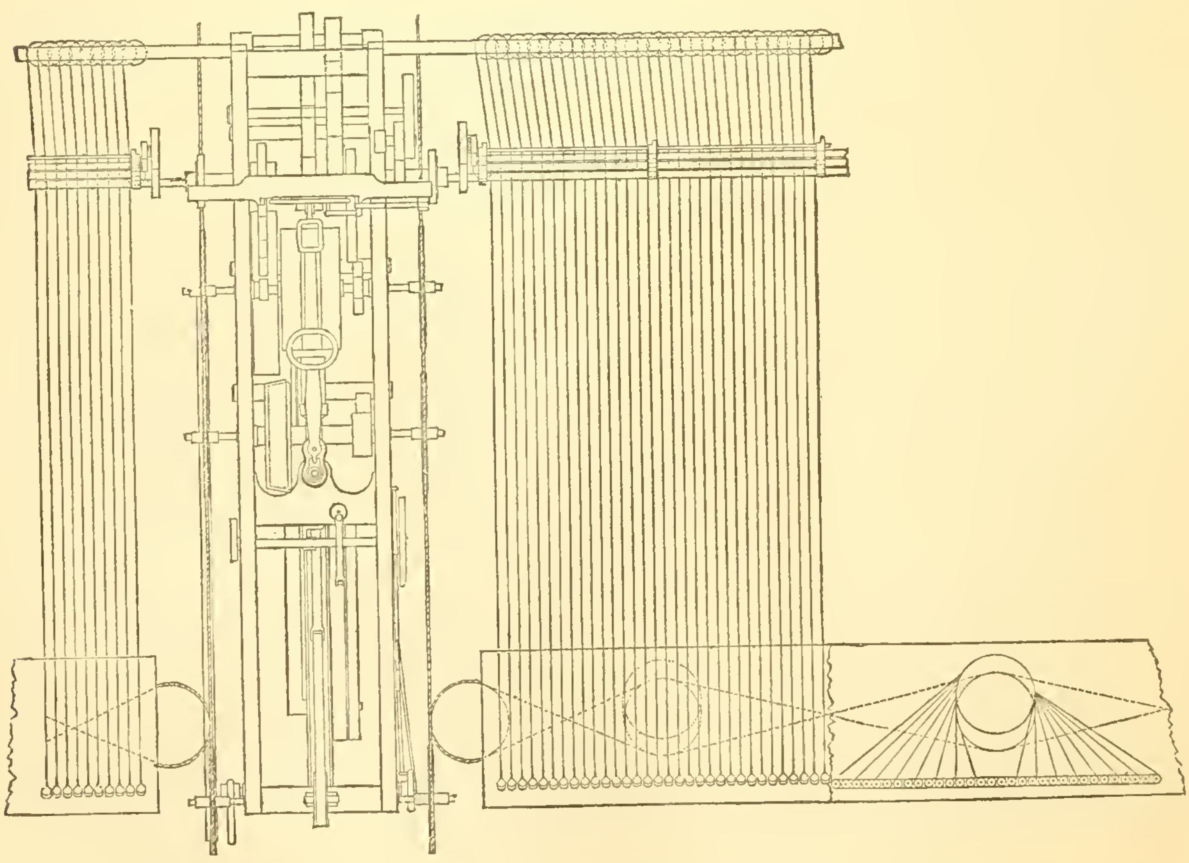
is called the *gaining* of the carriage. The space traversed by the carriage after the paying-out action of the rollers is stopped is called the *second stretch;* during this, the spindles are revolved very rapidly to save time. When the drawing, stretching, and twisting of the yarn are accomplished, the mule disengages itself from the parts of the machine by which it has been driven, and the carriage is returned to the rollers, the thread being then wound upon the spindle. The specific difference between the action of the throstle and the mule is, that the former has a continuous action upon the roving, drawing, twisting, and winding it upon the spindle; while the mule draws and twists at one operation as the carriage runs out, and then winds all the lengths upon the spindles as the carriage runs in.*

884.



*The Mason Self-Actor Mule.*—As an example of the best form of American construction of this machine, we present in Figs. 883 to 886 views of the self-actor mule constructed by Mr. William Mason of Taunton, Mass. Fig. 883 is a perspective view, Fig. 884 an elevation of the opposite side, and Figs. 885 and 886 plan and elevation of carriage and drawing-rolls. This mule differs

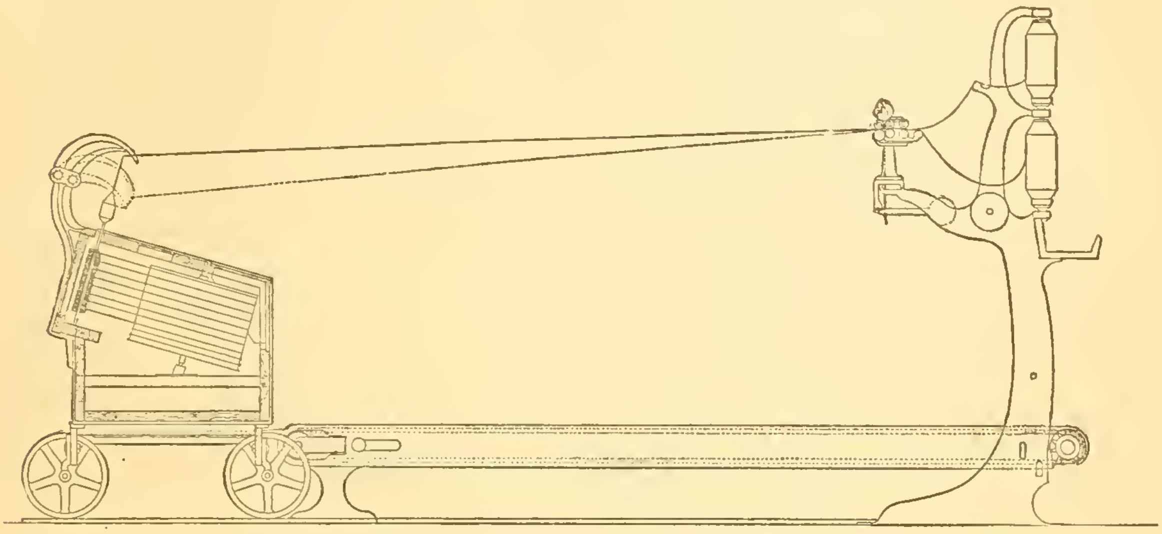
885.



* Knight's "Mechanical Dictionary."

from all others mainly in the manner in which all the movements appertaining specially to a self-actor are produced. In most other varieties the carriage is run in by means of a rope being wound upon a kind of spiral scroll-wheel, the grooves in which the rope winds commencing with a small diameter on one side, and increasing in diameter until the carriage has arrived at the middle of its course, and then diminishing on the other side of the scroll until the carriage reaches the end of the stretch. The carriage is then hauled out by another rope wound on a grooved cylinder that is uniform in diameter. These ropes need constant adjusting, as they are liable to stretch and vary with the changes in the weather. In the Mason mule the carriage is run in by a crank motion. A crank-pin is fixed in a large wheel, which by a pitman or connecting-rod is attached to a rack, the rack plying

886.

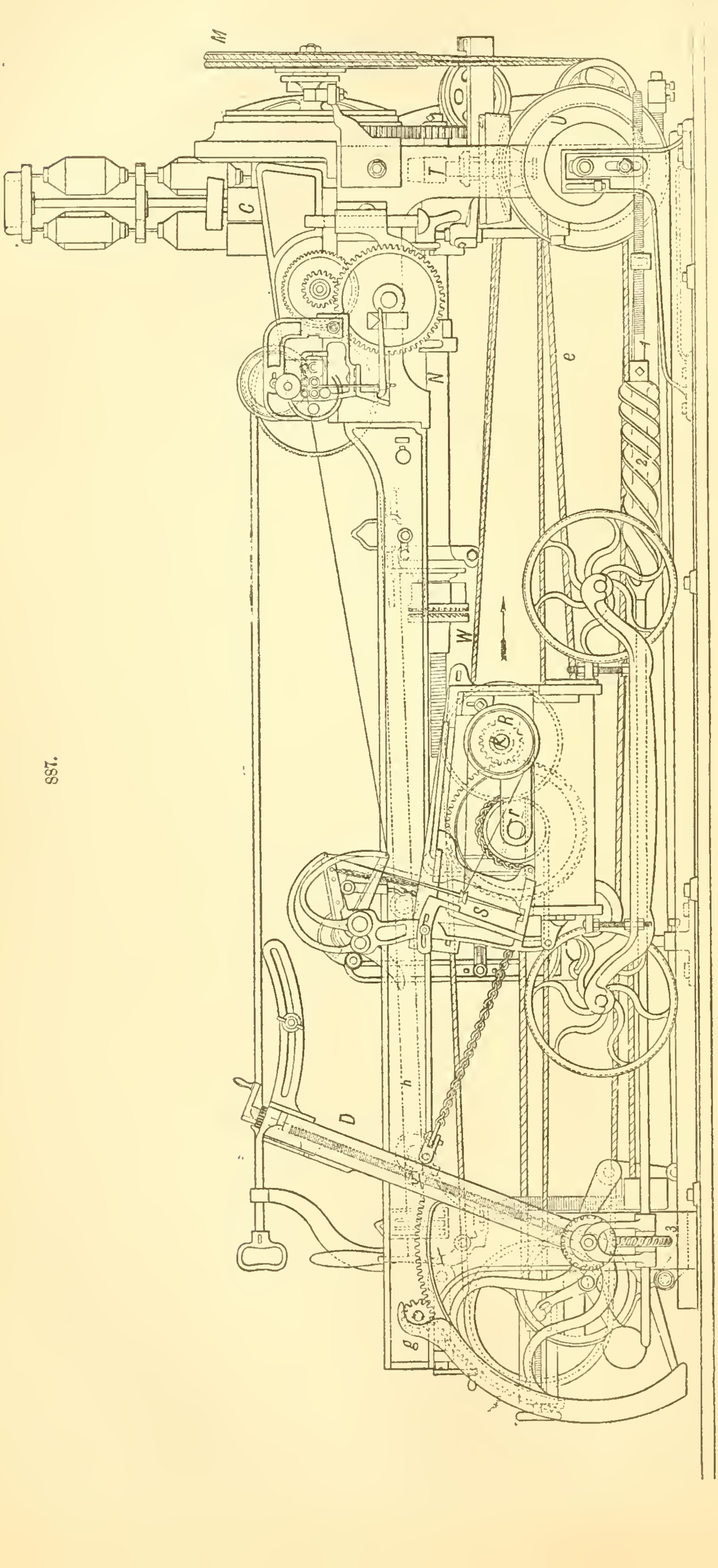


into a pinion-wheel, on the shaft of which is a large wheel that gears into another pinion on another shaft that extends the whole length of the mule on its back side near the floor. On this back shaft are a number of small chain-wheels, carrying endless chains that pass under the carriage and around small pulleys at the front of the machine. These chains may be two, three, or four in number, according to the length of the carriage and number of spindles. The carriage, being attached to the chains, is not only run in through the intervention of the train of machinery leading back to the crank, but is also drawn out by the same train independent of the crank, as will be described further on. The chains also hold the carriage perfectly square and straight. Thus the crank in running half a revolution will, through this train, run the carriage in and give it the same motion over its course as that of the piston of a steam-engine, which is the sweetest reciprocating motion that can be produced. The carriage can be run in in less time with this motion than any other, and it starts and stops at a dead point without the slightest concussion or jar. The drawing-rolls are driven from the main shaft through a train of gear-wheels, and the band-pulleys that drive the spindles are on the same shaft. The carriage is driven out by gearing extending from the front drawing-roll to the same train that runs it in. Thus, when the carriage arrives out, the crank has returned to the proper position to run it in again. The back-off motion and the depression of the faller are also produced by a crank through the medium of the necessary devices, which enables this operation to be performed quickly and smoothly without jerking or shaking. In the winding, a small quadrant is employed in combination with a cam, the shape of which is so arranged as to correct the imperfections of the quadrant as it is ordinarily used. These mules work very quietly and smoothly, without shocks or concussions, and can be run rapidly, and, it is claimed, with from 49 to 50 per cent. less power than other varieties.

The space required for a pair of mules depends upon the number and gauge of the spindles, and the relative position of the heads. If the latter are not set opposite to each other, a pair of mules can be erected in a width of 16 feet from outside to outside of creel-box; 18 feet gives ample room. To ascertain the length of a mule with any required number of spindles and gauge, multiply the number of spindles by the gauge and add 58 inches.

*The Parr-Curtis Mule.*—This mule, Figs. 887 to 890, is representative of the best English practice, and is built by Messrs. Curtis, Sons & Co., Phœnix Works, Manchester. It is based on, and improved from, the original mule of Richard Roberts. The motions are as follows: The rollers deliver the yarn, the carriage is taken out, and the spindles are turned by bands from drums to which motion is given by the twist-pulley *M*. The next motion is backing off the spindles to uncoil a sufficient quantity of yarn to allow the faller to descend, and carry with it the yarn to the point where it is to begin to be wound upon the spindles. The carriage is then drawn in, and the spindles receive the yarn, so distributed as to form a cop. Fig. 887 is a side view of the headstock, with the carriage in position of half stretch. Fig. 888 is a plan of the headstock, with a portion of the rollers on each side, and of the carriage in the same position as in Fig. 887. Fig. 889 shows the details of the regulator, and Fig. 890 the change-clutch mechanism.

Motion is given to the machine by the driving-pulleys *C*, which drive the twist-pulley *M* by the rim-shaft *I*, which, by means of the bevel-gears *A*, Fig. 888, also gives motion to the roller-shaft *B*, and through that, by the gears *n*, to the taking-out shaft *K*, on which a drum carries the band *L*, which passes around a carrier-pulley on the front of the headstock, and returns to the front of

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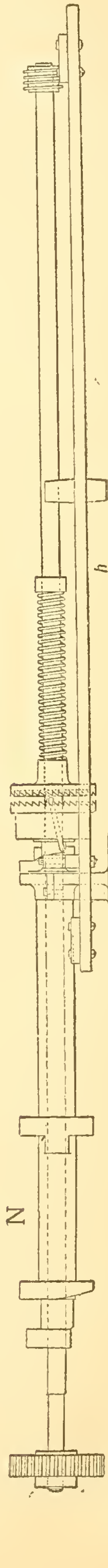
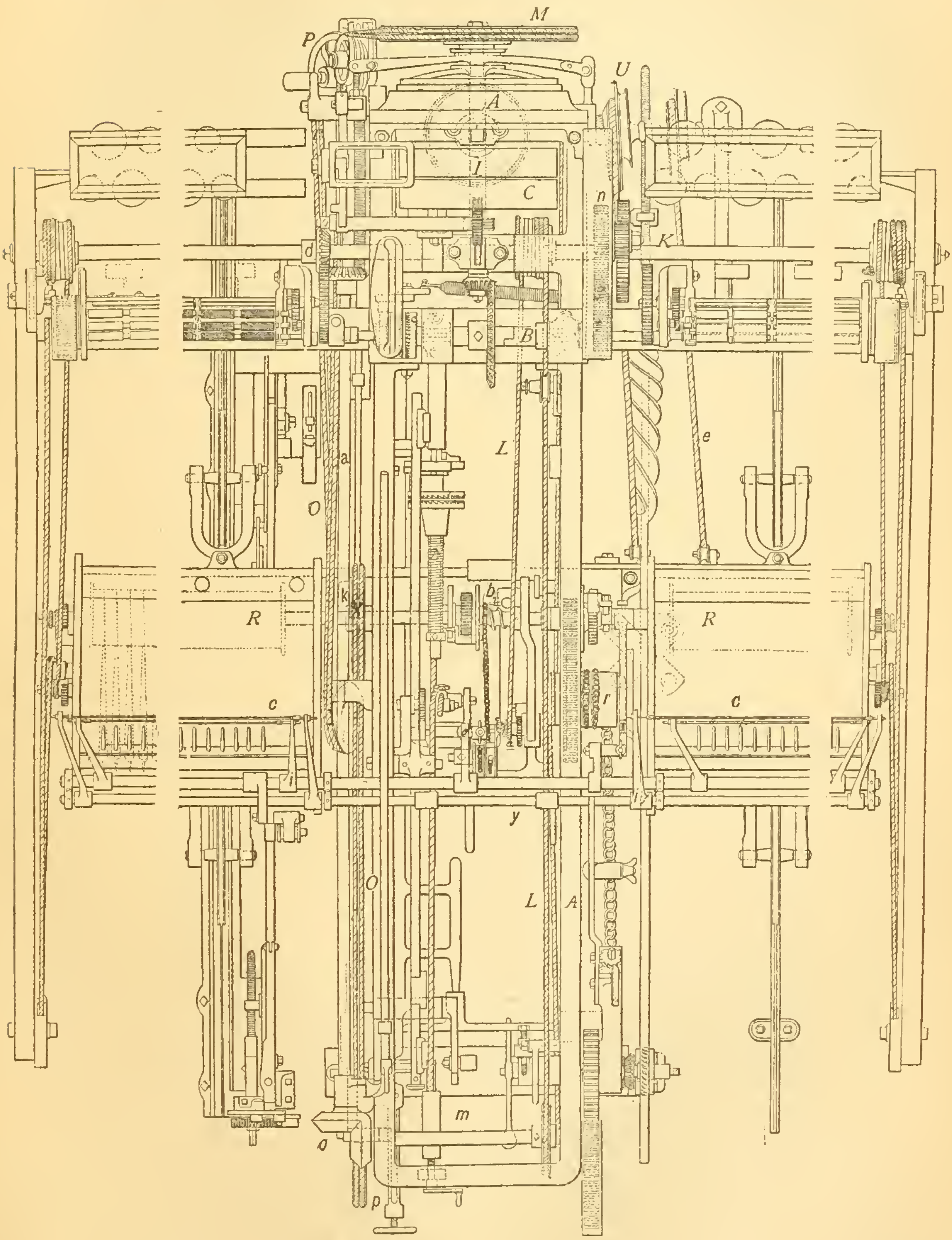



890.

the carriage; the other end being also fastened to the back of the carriage at $a$, and similar drums at each end of the shaft being connected to the ends of the carriage. The twist-band $e$ passes from the twist-pulley $M$ to the front of the headstock around the carrier-pulleys $P\ p$, driving in its passage the pulleys $k$ on the drum-shaft $R$, from which smaller bands are carried directly to the spindles $S$, Fig. 887. The upright shaft $T$, Fig. 887, is driven by bevel-gears on the hub of one of the pul-

888.




leys $C$, and, through another bevel-gear, gives motion to the winding-scroll $U$, Fig. 887, around which the band $e$ passes through the carriage, and is made fast to a take-up ratchet on the front side, and draws in the carriage to the roller-beam, when the stretch and twist are completed. When the belt is on one of the pulleys $C$, the carriage is drawn out, and the rollers are put in revolution, by the shafts $B$ and $K$, driven by the rim-shaft $I$; and when the stretch is completed, a spring

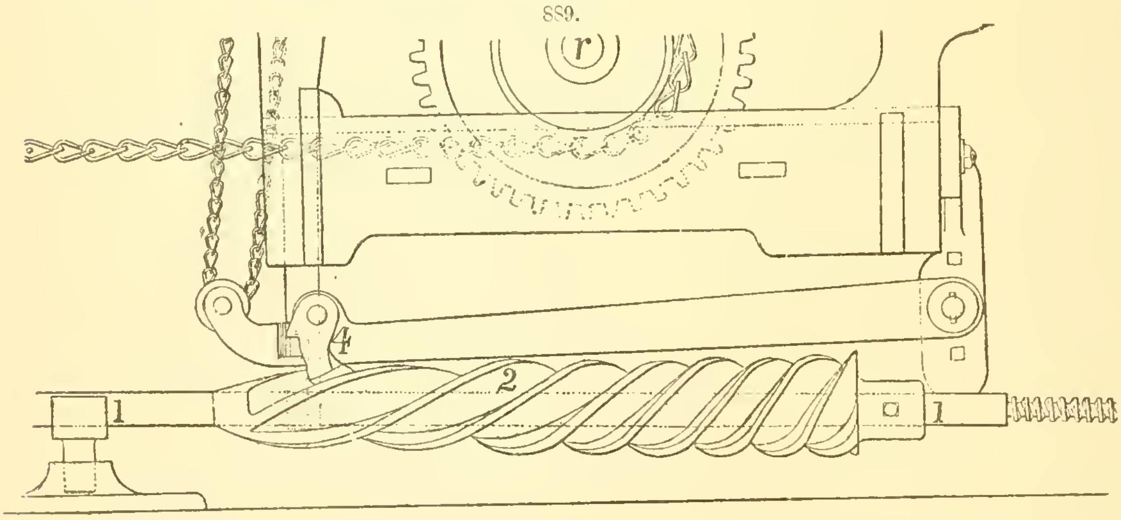
shipper throws the belt upon the other pulley *C*, which by the bevel-gear drives the shaft *T*, and by means of the scrolls *U* draws back the carriage to its starting-point. While the drawing-out shaft *K* is in operation, the shaft *a*, driven from it by the bevel-gears *d*, drives through the gears *o* the cross-shaft *m*, a pinion, *g*, Fig. 887, which works in the segment-gear *g* of the quadrant arm *D*, raising it to a perpendicular position. Down this arm runs a screw, as seen in Fig. 887, on which moves a nut to which is attached a chain, the other end of which passes round and is fastened to the drum *r* in the carriage, which is geared to the drum *R*, which drives the spindles. When the carriage is drawn in, this quadrant holds back on the chain, thereby revolving the drum *r*, and through it the drum *R*, giving motion to the spindles *S*, Fig. 887, and winding up the yarn already produced; the change of position of the nut on the quadrant, as the latter drops over to a horizontal position, increasing the tension of the chain, and consequently the speed of the spindles, as the yarn is wound from the larger diameter of the cop down to the smaller one of the spindle itself. By means of a ratchet and click the screw in this quadrant is given a rotatory motion, which carries the nut at each stretch further toward the end of the quadrant, thus describing increased arcs, and thereby causing the spindles to turn at each stretch more slowly at the beginning and more quickly toward the end of each winding-on, the faller-wire beginning the winding-on each time at a higher point on the spindle. When the double cone which forms the base of the cop is completed, the winding-on, guided by the quadrant *D*, remains constant, as the nut does not move any more, while the faller after each stretch continues to lay on the yarn successively at a higher point on the spindle. The faller and counter-faller shafts are shown at *y*, Fig. 888, operating arms *i i* and wires *c*. Motion is given to these from the scroll *b* on the drum-shaft, through the chain and lever shown. Their operation is too well known to need further description.

On a cam-shaft, driven from the upright shaft *T* by the bevels and pinion, are cams (not shown) for engaging and disengaging the clutch, which stops and starts the rolls as required, and also for stopping and starting the drawing-out motion. The change-clutch *W* (see Fig. 890) on this shaft, which effects these changes, is operated by the lever *h*, attached to the inside of the headstock, the cams on each end of which are struck and moved by rollers attached to the carriage as it reaches each end of the stretch, and which engages and disengages this clutch, one-half of which is fast to the sleeve *N*, sliding on the shaft, and the motion of which shifts the belt on the pulleys *C*, and effects the other changes mentioned above.

The backing-off motion is given to the twist-pulley *M* by a friction-clutch, which is put in operation for a few seconds when the belt is shifted from one pulley *C* to the other.

The regulator-shaft 1, with the snail 2, shown in detail in Fig. 889, is operated by a dog or finger

889.



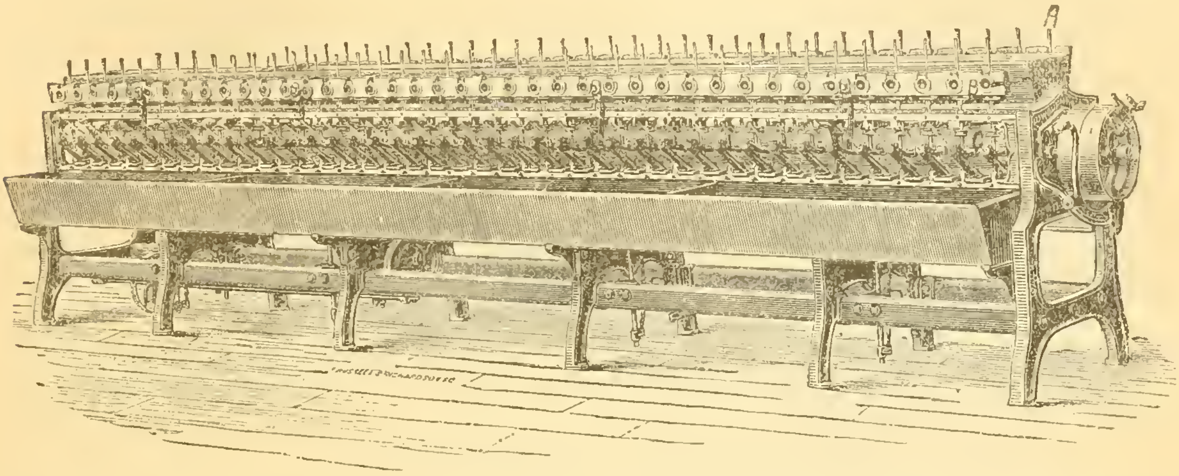

4, which is attached to the carriage and connected with the counter-faller. Should the yarn be wound too tight on the cop, the strain on the counter-faller depresses it, allowing the dog 3 to fall, so as to engage in the snail 2, and give a rotary motion to the shaft 1, which is communicated by the gear 3 to the screw on the quadrant, and releases the nut *v*, so as to slacken the strain a little. The screws on the quadrant *Q* and the regulator-shaft 1 are run back by hand when the cop is completed. It is impossible to describe all the details of the motions without a great number of engravings of parts; but it is believed that the above description will convey to a mechanic a sufficient idea of the operations of this mule.

VI. Spooling.—The yarn, having been taken from the spinning-frame, is now to be prepared for the loom, which is accomplished by the use of three consecutive machines, forming parts of one system, the first of which is the *spooler*, as represented in Fig. 891. This machine has a twofold purpose: first, to transfer the yarn from the small bobbin on which it is spun, containing from 1,200 to 1,800 yards, to a large spool, holding from 18,000 to 20,000 yards, which is done to save labor in the next operation of warping, by putting so many yards of yarn on the spool that the warper will not have to be stopped to piece ends; and second, by passing the yarn through a fine slot in the guide which leads it on to the spool, to detect lumps or weak places, either of which will break the yarn at the guide, and which being removed, and the sound thread tied with a firm and even knot, leaves it in condition to run through the warper without breaking.

The construction of this machine is very simple, consisting of merely a main cylinder or drum, driving from 60 to 120 strong upright spindles carrying the thread spools, with the accompanying bobbin-

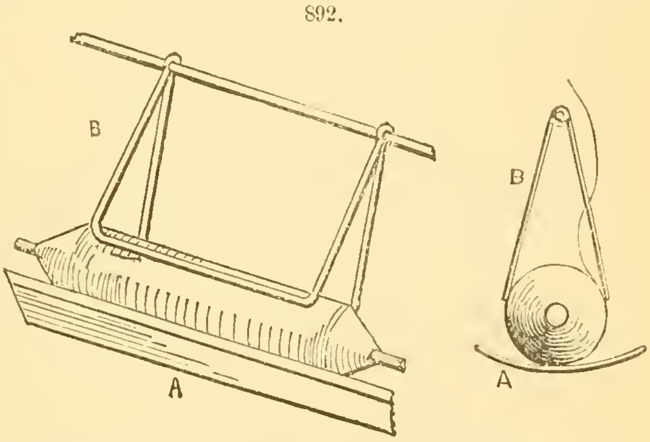
holders and thread-guides. The "Wade bobbin-holder," the invention of A. M. Wade of Lawrence, Mass., is a recent and valuable improvement, by which a semi-cylindrical cup or trough, *A*, Fig. 892, is substituted for the spindle formerly used to hold the bobbin from which the yarn is to be wound.

891.




The bobbin is simply laid in this cup, from which it is prevented from "jumping" by a pair of bent wires *B*, hung loosely from a pivot a few inches above, but allowing perfect freedom of rotation. This permits bobbins spun on any spindle to be spooled off equally well in the same spooler. The loosely hung wires close together as the bobbin is unwound, always keeping it in its place, but are so light as to cause less friction than was due to its rotation on the spindle formerly used. A spooler of 100 spools will require one-quarter horse-power, and spool off 2,000 lbs. of 30 yarn per week.

892.




VII. Warping.—The next machine is the *warper*, which prepares the yarn for the *dresser*. In the improved form of warper made by Messrs. George Draper & Son of Hopedale, Mass., a V-shaped frame, called a "creel," receives a sufficient number of the large spools, already filled, to form from one-eighth to one-fourth of the proposed warp, usually between 300 and 400—this being as large a number of threads as can be properly attended to at this machine. From this creel the threads are brought together into a flat sheet between a pair of guide-bars drawn through a "reed," which spaces them at equal distances, and then pass between a pair of light rollers over a movable or rise roll, through a second pair of rolls, and then through what is called the warper-box, which consists of a frame carrying a number of light hooked wires equal to the number of threads to be warped. In this machine as described these wires are loosely hinged, in such a manner as to fall backward when not kept in a nearly perpendicular position by the friction of the threads, over one of which each wire is hooked. From the wires the yarn goes to the "section-beam," so called, on which it is wound, and to which is communicated the power to drive the machine.

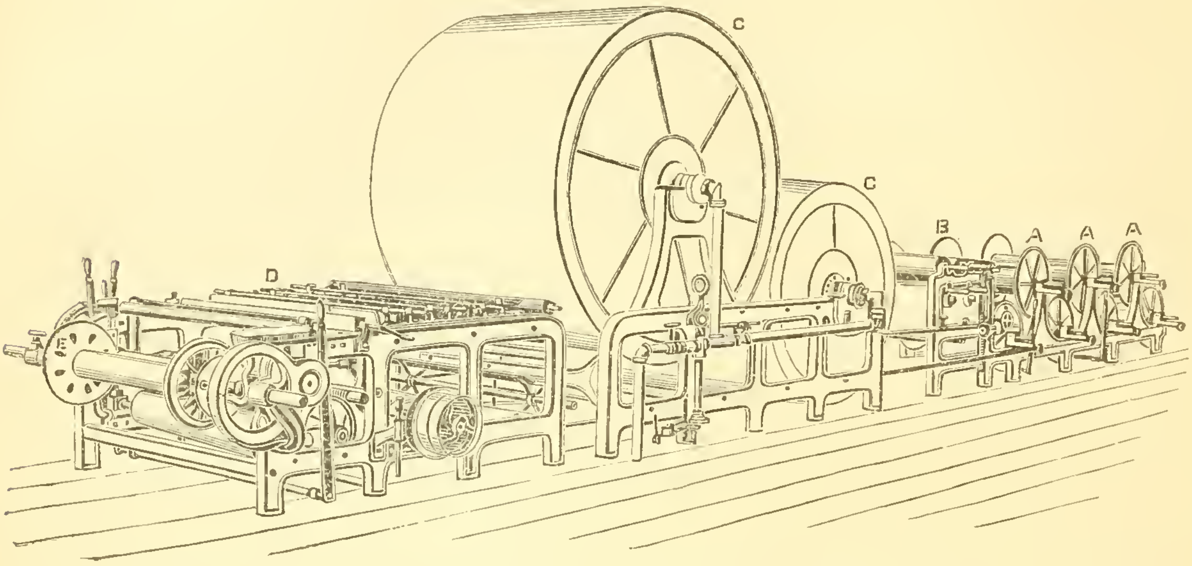
So long as all the threads are unbroken, the machine once started runs smoothly; but if one thread breaks, its wire falls backward to a horizontal position, and catches in a light "vibrating bar," the interruption of the motion of which, by means of a spring and lever, throws off the driving belt and stops the machine. The "rise-roll" now comes into operation; and being so hung in slotted guides at either end as to have perfect freedom of motion perpendicularly, and so balanced by weights underneath as always to lift with gentle pressure, it at once rises sufficiently to "take up the slack" of the yarn, which for an instant continues to be delivered by the spools, the motion of which is not arrested by the stopping of the machine. After the broken thread is mended by the attendant, the wire is lifted to its place, and the machine is again started. When the section-beam is filled, it is removed and taken to the dresser.

VIII. Dressing.—The dressing machine at present entirely superseding all others is an English invention, known as the "slasher" dresser; and Fig. 893 represents the most improved form as built by the Lowell Machine Shop, in which *A A* are the section-beams, as taken from the warper, *B* the size-trough and "squeeze-rolls," *C C* the drying cylinders, *D* the lease-rods, and *E* the loom-beam on which the warp as finally prepared for the loom is wound.

The section-beams, having been filled at the warper, are taken to the "slasher," where four or more, as required to form the warp, are placed in their positions, and the yarn from them is then carried through hot starch, kept so by a steam-pipe, in the size-box *B*; and the superfluous size being squeezed out, while the body of the thread is by the same pressure well filled, it passes around the large drying cylinders *C C*, made of copper or galvanized iron, then through the lease-rods *D*, where the threads are separated, and is finally wound on the loom-beam *E*. In order to form the

"lease," so called, by which the threads are separated into two equal parts or "sheds" for the weaver, a piece of thread or string is passed between the threads coming from the section-beams, at the first start, so as to divide 2 from 2, or 3 from 3, as may be; after passing the drying cylinders one of the iron lease-rods is substituted for this string, and the different threads of each half are further subdivided by the successive ones, so that no two threads shall be stuck together by the size. As each beam is filled a fresh lease-string is run through for the use of the weaver. Another form

893.




of slasher, instead of drying cylinders, passes the yarn through a closed box heated by steam-pipes, in which the air is kept in circulation by a fan. This form is by some considered preferable for fine yarn.

*Works for Reference.*—"Hand-Book on Cotton Manufacture," Geldard, New York, 1867; "The Science of Modern Cotton-Spinning," Leigh, London, 1876. S. W.

COUPLING, CAR. See Railway Car.

COUPLINGS AND CLUTCHES. Couplings for shafts are divided into two classes, couplings (proper) and clutches. The chief difference between the two is, that a coupling is a permanent connection, or rather one which requires some time and labor to take apart, while a clutch is a junction that can be disconnected instantly by suitable mechanism embodied in it. Whatever the form of coupling used, it should be of such a nature that the strength and rigidity of the line of shafts shall be at least as great at the joints as elsewhere.

Couplings.—One of the simplest forms of coupling is the flange or plate coupling. This, as shown in Figs. 894 and 895, consists of two flanges fitted independently to the ends of the shafts to be united, and then secured together by through bolts *a a*.

Some millwrights have contented themselves with fitting the flanges loosely to the shafts, and driving in a taper key or wedge to secure them in place; but this is always bad practice in either couplings or pulleys, as the taper key tends not only to burst the hub, but also to confine the contact to a single line, and thus to increase the chances for it to work loose. The plate-coupling, fitted accurately and forced on the shafts under pressure, faced up in place, and secured by closely-fitting bolts in reamed holes, is undoubtedly qualified to fulfill the requirements of strength and rigidity; but it is open to three serious objections: it requires skilled labor and additional time to fit the shaft to the coupling; it necessitates the use of open-sided or hook hangers, which are needlessly heavy and expensive; and finally, it involves the use of pulleys made in separate halves, to be bolted together upon the shaft. These disadvantages—all entailing increased first cost and constant inconvenience whenever it becomes necessary to disconnect the shafts in order to change pulleys or for any other purpose—finally led to the introduction of adjustable couplings. These have almost entirely supplanted the plate-coupling in the United States, and have made large progress abroad. Numerous patterns, all more or less successful, are now made. For description we select one of the oldest of them, and one which is claimed to fulfill best the conditions of a perfect adjustable coupling. These may be enumerated as follows: it must secure the shafts so that their axes will form a continuous straight line; it must be rigid and strong, as already noted; it must grasp each shaft-end independently, but with the same force; it must be able to accommodate itself to slight differences in diameter, and must do this without being thrown out of centre; it must be easily and quickly put on and taken off; and it must be cheaply made. The *patent double-cone vise-coupling*, Figs. 896 and 897, made by Messrs. William Sellers & Co. of Philadelphia, consists of three principal parts, an outer sleeve *a* and two internal sleeves *b b*, Fig. 897. The external sleeve is cylindrical outside, but is bored a double taper inside; that is, its inner surface has the form of two conical frusta meeting in the centre of the coupling. The internal sleeves are bored to fit the shaft, and are turned outside to fit accurately into

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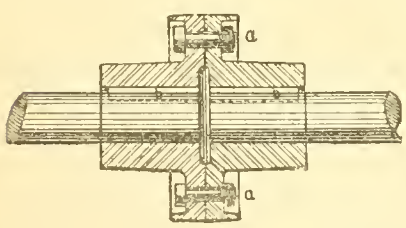


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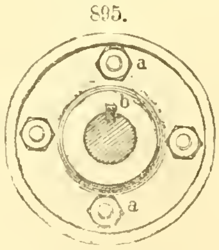

the taper holes in *a*, but are large enough to remain say three-eighths of an inch apart when put into the opposite ends. Both the shell *a* and the cones *b b* are provided with slots in which may fit the square bolts *c c c*; and the latter have also a keyway in the centre, and are rendered elastic by slotting quite through in one of the bolt grooves. If now the cones be put into the shell, the bolts inserted, and the nuts screwed down, it will be seen at once that the cones will be forced into the shell, will contract in doing so, and will bind on the shaft with a force proportioned to the power exerted to drive the cones into the shell; and it is manifest that this acts in no way to spoil the alignment of the shafts or to throw the coupling out of centre. The fundamental principle of the Sellers coupling is the use of an external sleeve surrounding two flexible internal sleeves, which grasp the end

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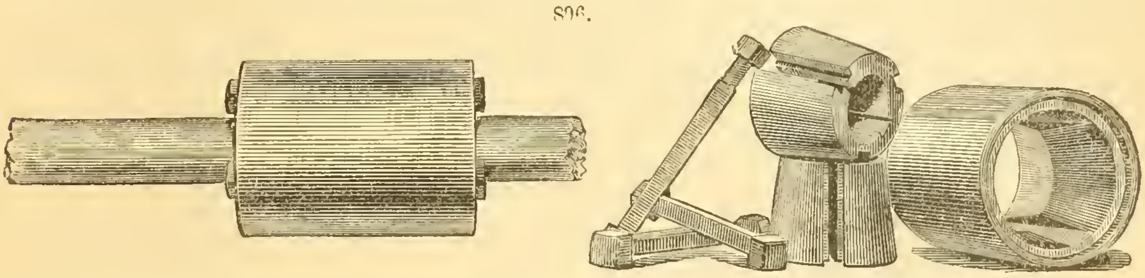

of each shaft independently; and this principle, first applied in this device, is that upon which all of the better class of adjustable couplings have since been made. When coupling together shafts of different sizes, it is best to reduce the larger size to the smaller, and to use a coupling of that size, thus saving in weight and first cost (Fig. 898).

Special couplings have been devised to connect shafts whose axes do not form a continuous straight line. For this purpose strong spiral (or helical) springs have been used; but probably the best known device is what is known as Hooke's universal joint, from the inventor, Dr. Robert Hooke. The object of this coupling is to unite shafts which are inclined to each other in the line of direction, and which do not therefore admit of being rigidly connected, as in ordinary cases. This coupling is very

897.

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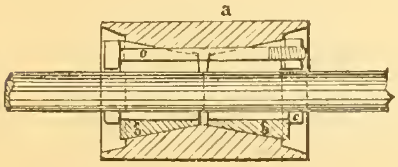

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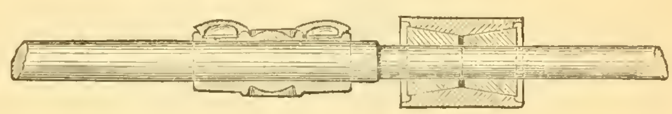
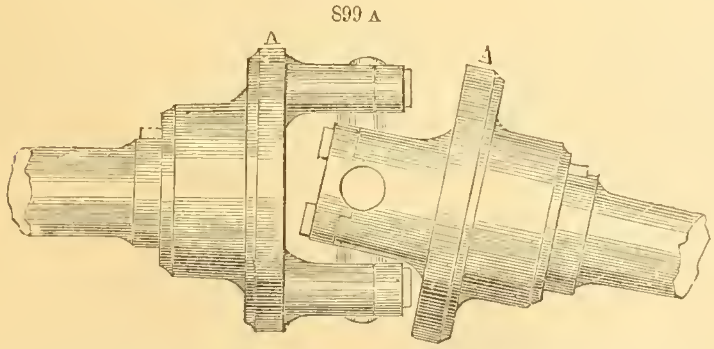


commonly employed in light machinery, as in steeple clocks, for taking off the index-motion, and is then usually constructed by forming an arc on the two extremities which it is intended to connect, and forming the joint by a central cross $\left(\begin{smallmatrix} a \\ b+b \\ a \end{smallmatrix}\right)$, the extremities of the arc on the end of one shaft being jointed to the arms *a a*, and the extremities of the arc on the other shaft to the arms *b b*, at right angles to the former. But this simple mode of construction is not adequate to the purposes for which the coupling is required in a line of shaft-gearing; in this case, although the principle is not in any way changed, the construction is much more substantial. Figs. 899 A and 899 B represent a form of it adapted to heavy strains. *A* is a strong disk keyed on the end of each shaft, carrying a

899 A

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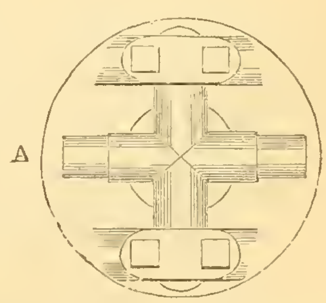


pair of bearings for the reception of the gudgeons formed on the extremities of the cross. Fig. 899 B is a face view of one of the disks, showing the cross in its place, with its alternate journals disengaged. In Fig. 899 A the shafts are shown at nearly the limit of the angle to which the single joint ought to be applied. This angle ought not to exceed 15°; when a higher angle is introduced, the rotatory motion becomes very sensibly irregular, and the friction is greatly increased. This defect may be obviated by using a double joint.

Clutches.—Of these devices there are two kinds—those which cause a positive engagement or interlocking of the connected parts, and those which determine the junction of the latter by close frictional contact. The weight of advantage is in favor of the latter system, through its preventing the shock otherwise due to the sudden starting of the machinery.

In the clutch represented in Fig. 900, which belongs to the former class, *a* and *b* are the two parts of the coupling, formed on the acting faces into alternate projections and recesses, such as they

correspond to, and exactly fitting into each other when in gear. The part *a* is, in this example, cast on a spur-wheel, from which the motion of the shaft is supposed to be taken off. Both of the parts *a* and *b* are to a certain extent loose on the shaft; the former being capable of moving round on it, though deprived of longitudinal motion by washers and pins marked *c*, and the latter being free to slide on the shaft, though prevented from turning on it by a sunk key, which slides in a slit inside the *clutch* or sliding piece *b*. The mechanism is put into gear by means of the handle *d*, which terminates in a *fork* with cylindrical extremities *c*; and it is obvious that by the contact of the flat faces of *a* and *b*, the latter will immediately carry with it the other part at the same speed as the shaft. Supposing, now, that the motion of the wheel *a* is suddenly accelerated, the oblique faces of the couplings immediately fall out of contact, and slide free of each other, leaving the couplings clear, and the shaft free to continue in motion. In the old form of this contrivance, known as the sliding bayonet clutch, the part *b*, instead of the tooth-like projections on the face, had two or more prongs which laid hold of corresponding snugs cast on the face of the part *a*—which, moreover, was

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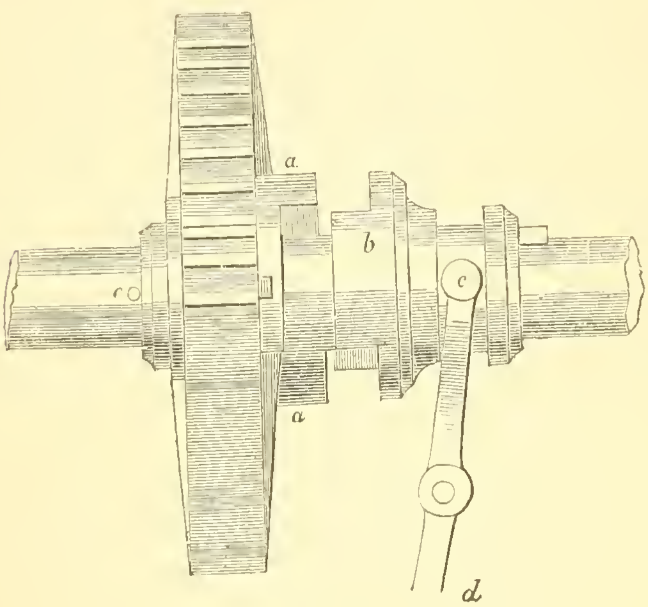


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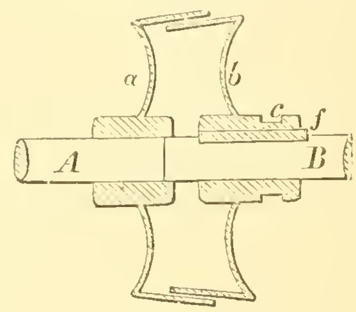
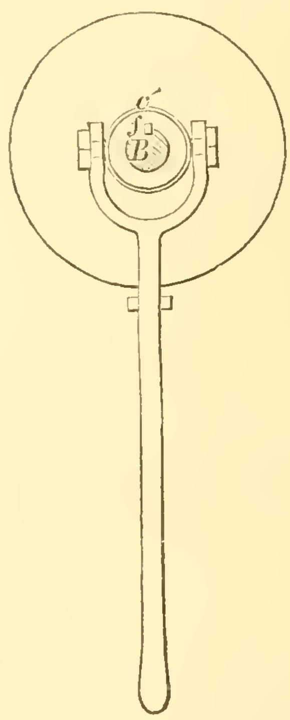



901 B.

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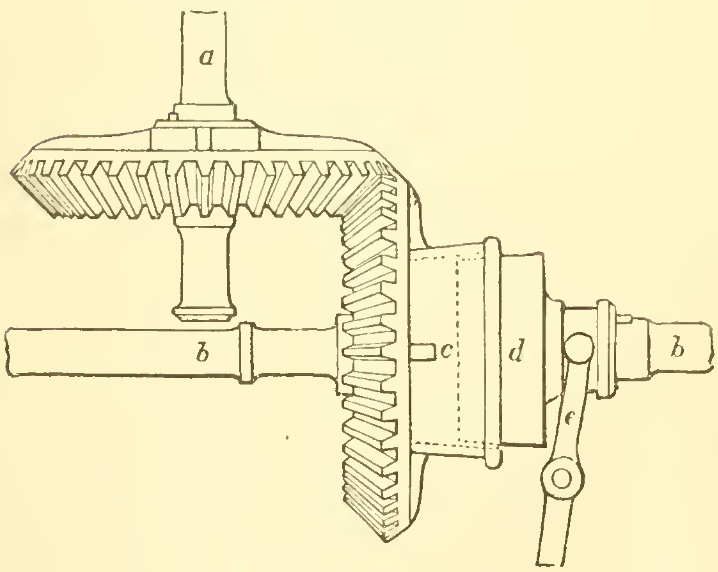


usually a broad-belt pulley introduced with a view to modify the shock on the gearing on throwing the clutch into action. In an older form still the pulley was made to slide end-long on the shaft. A form analogous to this was known as the "lock-pulley." Instead of the end-long motion common to the other modes, the parts were "locked" together by a bolt fixed upon the side of the pulley, and which, when shifted toward the axis, engaged with an arm of a cross, of which the part *b*, in Fig. 900, is the modern representative. The bolt was worked by means of a key and stop, the turning of the key throwing back the bolt, and thereby unlocking and disengaging the pulley.

One of the simplest forms of frictional clutches is the friction-cone clutch represented in Figs. 901 A and 901 B. It consists of an exterior and interior cone, *a b*; *a* is fastened to the shaft *A*, while *b* slides in the usual way on the feather *f* of the shaft *B*; pressing *b* forward, its exterior surface is brought in contact with the interior conical surface of *a*; this should be done gradually; the surfaces of the two cones slip on each other till the friction overcomes the resistance, and motion is transmitted comparatively gradually, and without danger to the machinery. It must be observed

that the longer the taper of the cones, the more difficult the disengagement; but the more blunt the cones, the more difficult to keep the surfaces in contact. The limiting angle of resistance for surfaces of cast-iron upon cast-iron is 8° 39′, and this angle with the line of shaft will give a very good angle for the surfaces of the cones of this material. When thrown into gear, the handle of the lever or *shipper* is slipped into a notch, that it may not be thrown out by accident.

Another friction-cone clutch is represented in Fig. 902. The two parts of this coupling, *c* and *d*, are arranged on the shaft *b*, in the same manner as in Fig. 900. *a* is a shaft driven by means of bevel-gear off the main shaft *b*, its motion being derived from the latter shaft through the coupling. *c* is an interior cone cast upon the back of the bevel-wheel; *d* is an exterior cone having the same taper as the cone *c*, such that by means of the handle *e* it may be moved into contact with the interior cone. The surfaces being supposed to be well fitted to each other, the cone *d* will by its friction drive the cone *c*, and thereby also the upright shaft. When either of the shafts *a* or *b* is accidentally stopped, the cones immediately fall out of gear, and the connection is broken. They are held in gear by means of a screw, or more commonly, and perhaps better, by a weight.

Another mode of accomplishing the same purpose in small machinery, by means of an epicyclic train, is represented by Fig. 903. In this the shaft *A A* is continuous, and supposed to be that through which the motive power is transmitted. The wheel *a* is fast, but the wheels marked *b* and *c* run loose on this shaft. The two pinions *d d* have their bearings in the wheels *c c*, and gear with the two opposite bevel-wheels, *a* and *b*. (One of these pinions only is requisite to complete the motion, the second being introduced merely to maintain the equipoise of the system.) If now motion be given to the shaft *A A*, it is clear that the wheel *b*, which is loose, will be made to revolve in the contrary direction to the wheel *a*, which is fixed, by means of the carriers *d d;* but no motion of the wheel *c*, *if slightly opposed*, will ensue; and so long as this last remains at rest, the wheels *a* and *b* will have the same angular velocity in opposite directions. But if the motion of the wheel *b* be opposed by means of a friction-gland *e*, which can be tightened by means of the T-screw marked *f* to any degree required, the teeth of that wheel will serve as fulcra to the carrier pinions *d d*, which, becoming levers of the second kind, with the resistance at their axes, will carry round the wheel *c* with half the velocity of the prime mover *a*, and, gearing with the wheel *h*, on the main spindle of the machine to be impelled, will transfer to it the motion which itself receives. We have supposed the wheel *b* to be held absolutely still, but it is obvious that it may be brought gradually to rest by means of the friction-gland; and as the wheel *c* can attain motion only as the motion of the wheel *b* is reduced, and can attain its full speed only when *b* is brought to rest, it is clear that the wheel *h*, and consequently the machine, may be brought into action without the slightest degree of shock, and may moreover be driven at any velocity less than the maximum that may be desired.

Another mode of obviating shock in starting machinery, which has been long in use, is represented by Fig. 904. On the shaft *B* is fixed a drum or pulley, which is embraced by a friction-band *a* as tightly as may be found necessary; this band is provided with projecting ears, with which the prongs *b b* of a fixed cross on the driving-shaft *A* can be shifted into contact. This cross can be shifted end-long on its shaft *A*, but is connected to it by a sunk key, so that, being thrown into gear with

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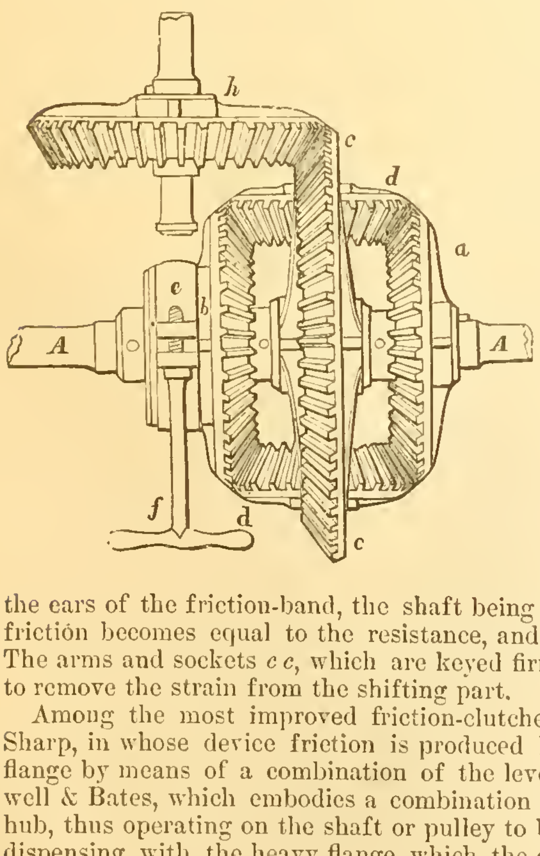


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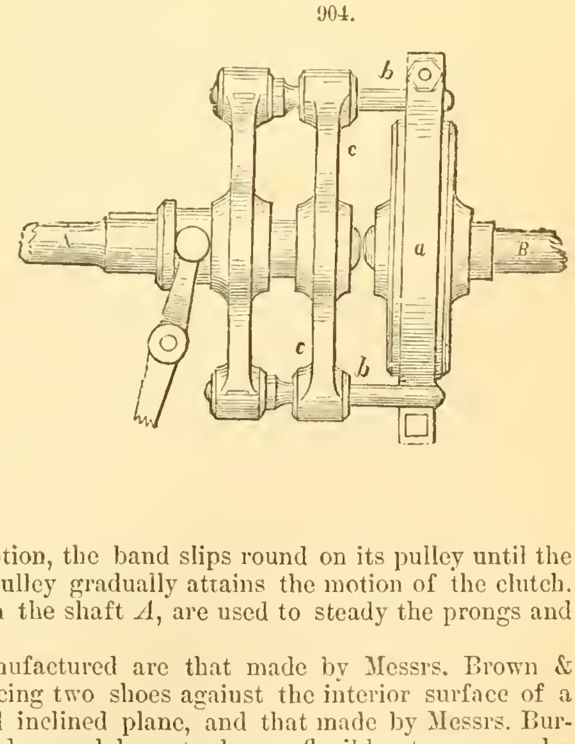
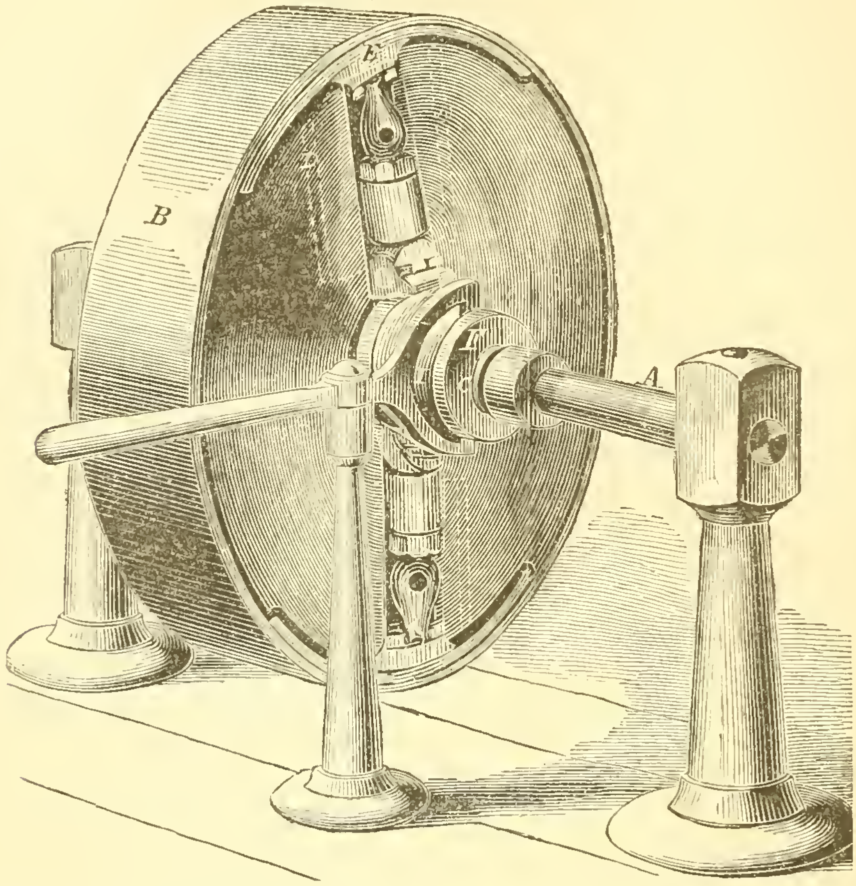



the ears of the friction-band, the shaft being in motion, the band slips round on its pulley until the friction becomes equal to the resistance, and the pulley gradually attains the motion of the clutch. The arms and sockets *c c*, which are keyed firmly on the shaft *A*, are used to steady the prongs and to remove the strain from the shifting part.

Among the most improved friction-clutches manufactured are that made by Messrs. Brown & Sharp, in whose device friction is produced by forcing two shoes against the interior surface of a flange by means of a combination of the lever and inclined plane, and that made by Messrs. Burwell & Bates, which embodies a combination of wedges and lever to draw a flexible strap around a hub, thus operating on the shaft or pulley to be moved with less leverage than the other devices, but dispensing with the heavy flange which the others require. Fig. 905 represents the Mason clutch, which is manufactured by Volney W. Mason & Co. of Providence, R. I. A movement of the sleeve

$F$ along the shaft $A$ forces out or draws in the segments $E$, whose adhesion to the flange $B$ makes the required friction, which may be regulated in amount by the adjustable arms of the toggle-joint.

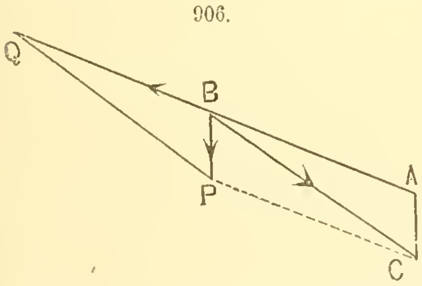
905.




The clutch should be so placed that when in action the toggles will have passed a trifle beyond the straight line, so that there will be no tendency for them to fly out or to produce a pressure on $F$ or on the shifting lever.

CRANES AND DERRICKS. The common lifting crane consists of an arm or jib jointed to a post. From the outer end of this arm a tie connects with the post. A weight suspended from the end of the jib then tends to pull the latter downward, but the tie holds it back and is thus brought into a state of tension. The jib is at the same time pushed downward on its joint, and is therefore a strut. Thus the downward pull of the weight is by this contrivance decomposed into two forces, one of which is resisted by a tie, the other by a strut. The strains on these portions are determined as follows: Through $C$, Fig. 906, draw $C\,P$ parallel to the tie $A\,B$, and $P\,Q$ parallel to the strut $C\,B$; then $B\,P$ is the diagonal of the parallelogram whose sides are each equal to $B\,C$ and $B\,Q$. Let $B\,P$ be considered to represent a downward-pulling force of 20 lbs. This may be decomposed (see STATICS) into the forces represented by $B\,Q$ and $B\,C$. But $A\,B$ is equal to $B\,Q$, since each of them is equal to $C\,P$; also $B\,P$ is equal to $A\,C$. Hence, the weight of 20 lbs. being represented by $A\,C$, the strain along the tie will be represented by the length $A\,B$, and that along the strut by the length $B\,C$. If we suppose $A\,B$ to be 3 feet long, $C\,B$ to be 3 feet 6 inches, and $A\,C$ 1 foot, it follows that the strain along the tie $A\,B$ equals ($3 \times 20$) 60 lbs., and along the strut ($3.5 \times 20$) 70 lbs., when the weight of 20 lbs. is suspended. In every other case the strains along the tie and strut can be determined when the suspended weight is known by the proportionality to the sides of the triangle formed by the tie, the jib, and the upright post.

906.

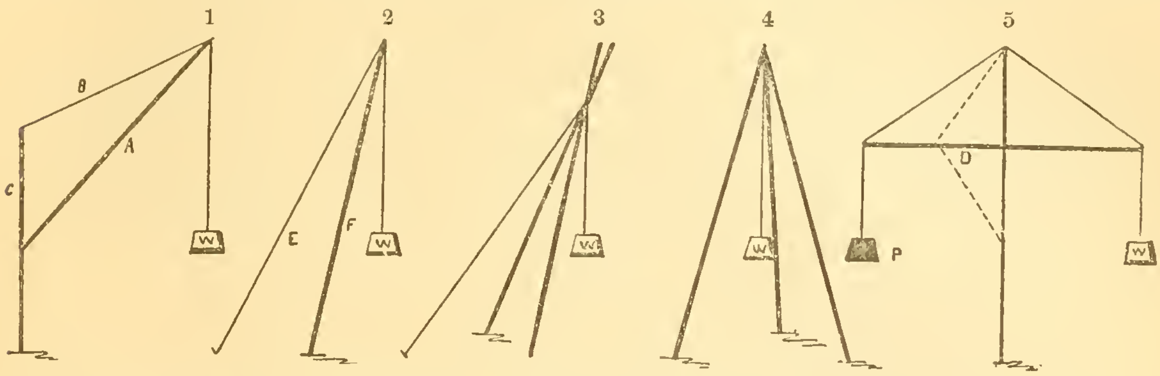



Suppose, however, that in practice the engineer is called upon to erect a crane to sustain a weight of 10 tons, according to the numerical proportions we have employed for illustration: the strain along the tie-rod would be 30 tons, and therefore the tie must at least be strong enough to bear a pull of that extent; but it is customary in good engineering practice to make the machine of about ten times the strength that would just be sufficient to sustain the ordinary load. Hence the crane must be so strong that the tie-rod would only be broken by 100 tons suspended from the chain; that is, by a strain of 300 tons upon the tie-rod. This large increase is necessary on account of the jerks and other occasional great strains that arise in the raising and lowering of heavy weights. For a crane intended to raise 10 tons, the engineer must therefore design a tie-rod which not less than 300 tons would tear asunder; and knowing the strength of the proposed material per square inch of section, it is easy to determine a section of tie-rod capable of withstanding the strain noted. In the same way, the strain on the jib amounting to 35 tons, the jib should be ten times as strong as a strut which would

collapse under that strain. It is also necessary to secure the upright support very firmly to resist the pull of the tie. The hoisting machine may of course be of any suitable form. (For a complete graphic demonstration of the properties of cranes, etc., see "Experimental Mechanics," Ball, New York, 1871.)

The same considerations apply to the structures known as derricks and shears. Thus a crane represented at 1, Fig. 907, possesses essentially a jib *A*, tie *B*, and post *C*. The derrick 2 has a

907

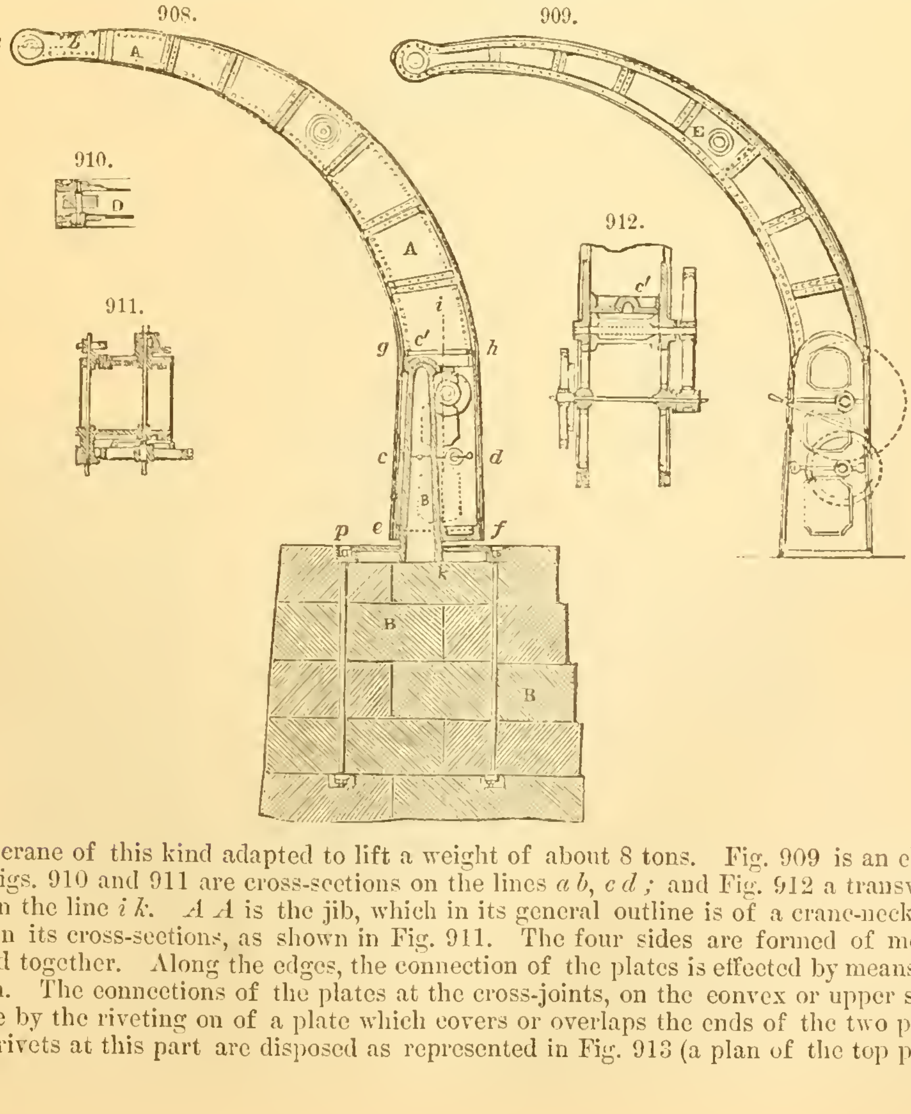



single strut *F*, sustained by the guy *E*. Shears have two struts similarly sustained. The gin, 4, is merely a framework of three or more legs. There is still another structure forming a second class of derrick, namely, the boom derrick or balanced derrick, 5. In this case the boom *D* is swung to its mast at the middle, and the weight *W* is balanced by a counterpoise *P*. In some instances the opposite arm to that which sustains the weight is shortened and braced by guys leading to the mast above and below.

The distinction between the appellations crane, derrick, etc., is, however, not very minutely kept, and in many instances is practically disregarded. Thus a hoisting apparatus traveling on an elevated railway, so as to raise loads from beneath, is known as a traveling or overhead crane, although the essential features of the crane already noted are wholly absent.

Cranes.—In Fairbairn's tubular crane, the jibs are made of metal plates so arranged and combined as to form a connected series of tubular or cellular compartments. Fig. 908 is a vertical

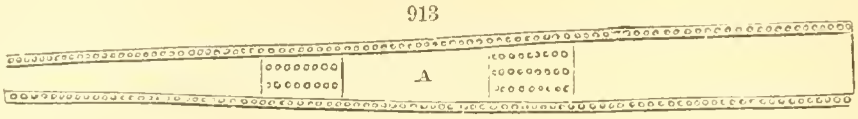
908. 909. 910. 911. 912.




section of a crane of this kind adapted to lift a weight of about 8 tons. Fig. 909 is an elevation of the same; Figs. 910 and 911 are cross-sections on the lines *a b*, *c d*; and Fig. 912 a transverse vertical section on the line *i k*. *A A* is the jib, which in its general outline is of a crane-neck form, but rectangular in its cross-sections, as shown in Fig. 911. The four sides are formed of metal plates firmly riveted together. Along the edges, the connection of the plates is effected by means of pieces of angle-iron. The connections of the plates at the cross-joints, on the convex or upper side of the jib, are made by the riveting on of a plate which covers or overlaps the ends of the two plates to be joined; the rivets at this part are disposed as represented in Fig. 913 (a plan of the top plates), and

known as "chain-riveting." *B B* is the pillar, which is firmly secured by a base-plate *p* to a stone foundation, and fits at the top into a cup-shaped bearing, which is firmly secured to the side-plates of the jib at or near to the point where the curvature commences, and on which bearing the

913




jib is free to revolve. Fig. 912 is a transverse vertical section of the lower part of the jib, showing the manner of fitting the bearings for the chain-barrel (which is placed in the interior), and the spindles and shafts of the wheel-gearing by which the power is applied thereto. *D* is the chain-pulley, which is inserted in an aperture formed in the top of the jib. The chain passing over this pulley enters the interior of the crane, and is continued down to the chain-barrel. *E* is a pulley or roller, which is interposed about half-way between the chain-pulley and the chain-barrel, for the purpose of preventing the chain from rubbing against the plates. Fig. 914 is a plan of the lower plates.

914.

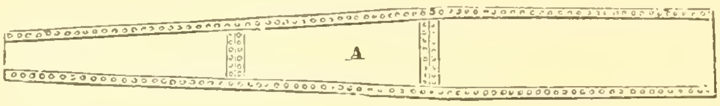
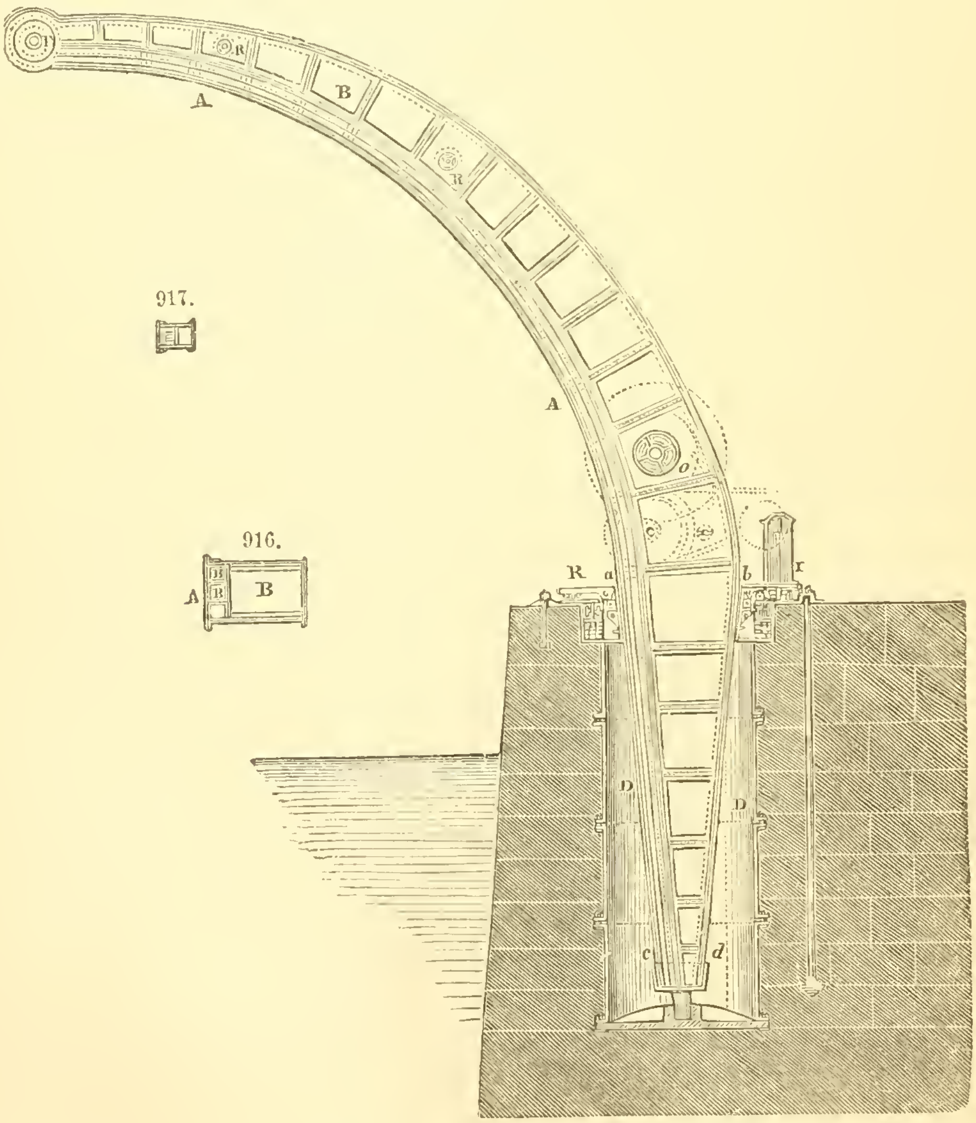



Fig. 915 is a vertical section of another crane, constructed on the same principle as that which has just been described, but calculated for lifting much greater weights (say 20 tons); it differs in having the lower or concave side *A A* of the jib strengthened by means of three additional plates, *B*, *B*, *B*, whereby the interior is divided into one large and three smaller cells, as shown in Figs. 916 and 917,

915.




917.

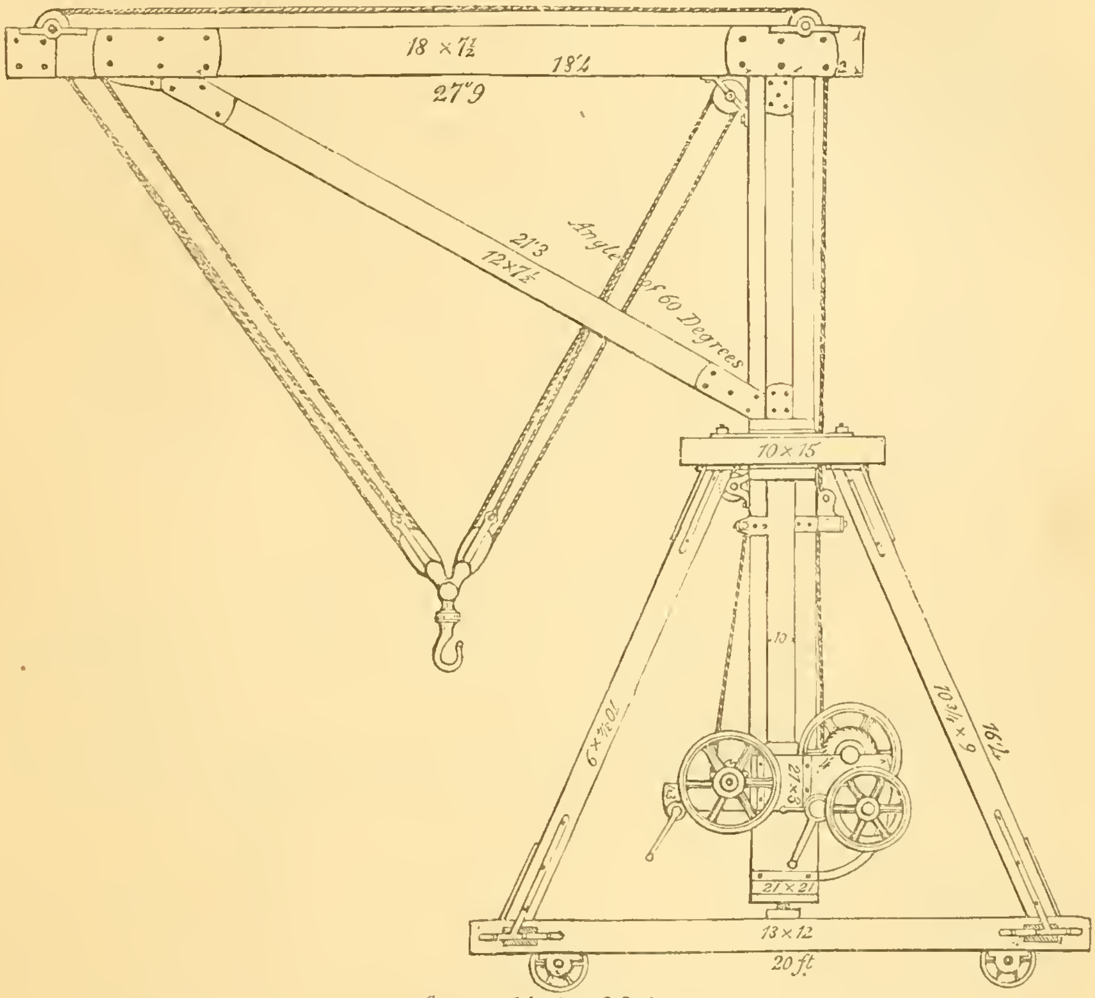
916.

which are cross-sections on the lines *a b* and *c d* of Fig. 915. This arrangement of the cells to strengthen the lower or concave side is advisable, in order to obtain sufficient resistance to the compression exerted by the load lifted, without unnecessarily increasing the weight of the other parts.

Fig. 918 represents an elevation, and Fig. 919 a plan, of a movable crane, arranged and used for

laying the voussoirs in the inverted arches of the United States Dry Dock at Brooklyn, New York, by Wm. J. McAlpine. This crane has been used for hoisting stone weighing from 10,000 to 15,000 lbs. at the extremity of the arm, which describes a circle of 50 feet diameter. It has also been used

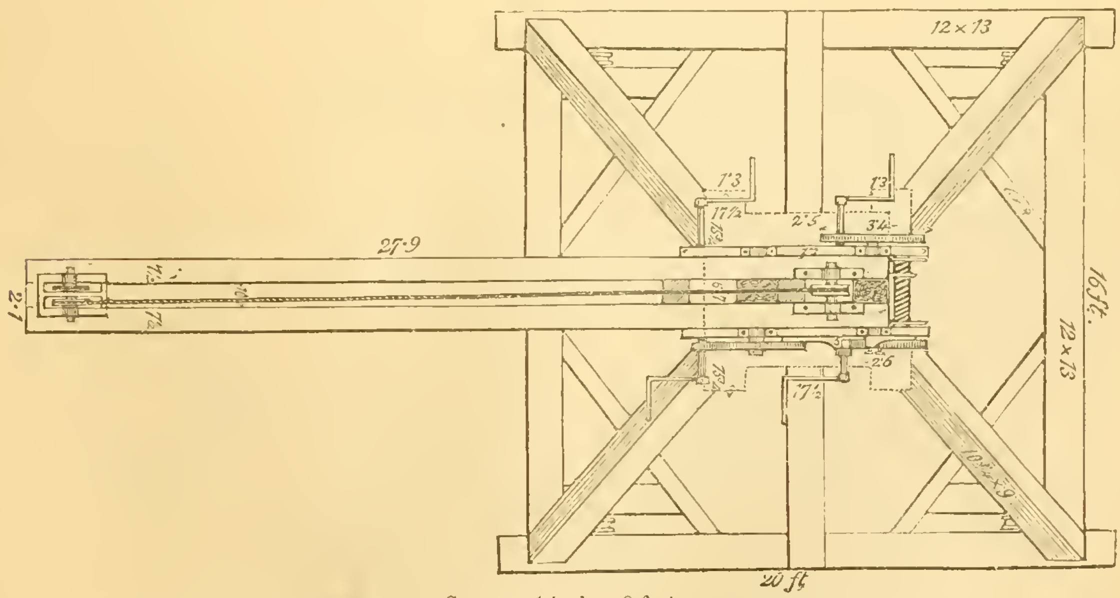
918.




Scale.—1 inch = 8 feet.

with an out-rigger, by which stones from 3 to 5 tons weight were hoisted 10 feet beyond the extremity of the arm. A similar crane was used by the same engineer in the construction of the locks of the enlarged Erie Canal. A movable sheave traversed along the arm of the crane, which was laid

919.



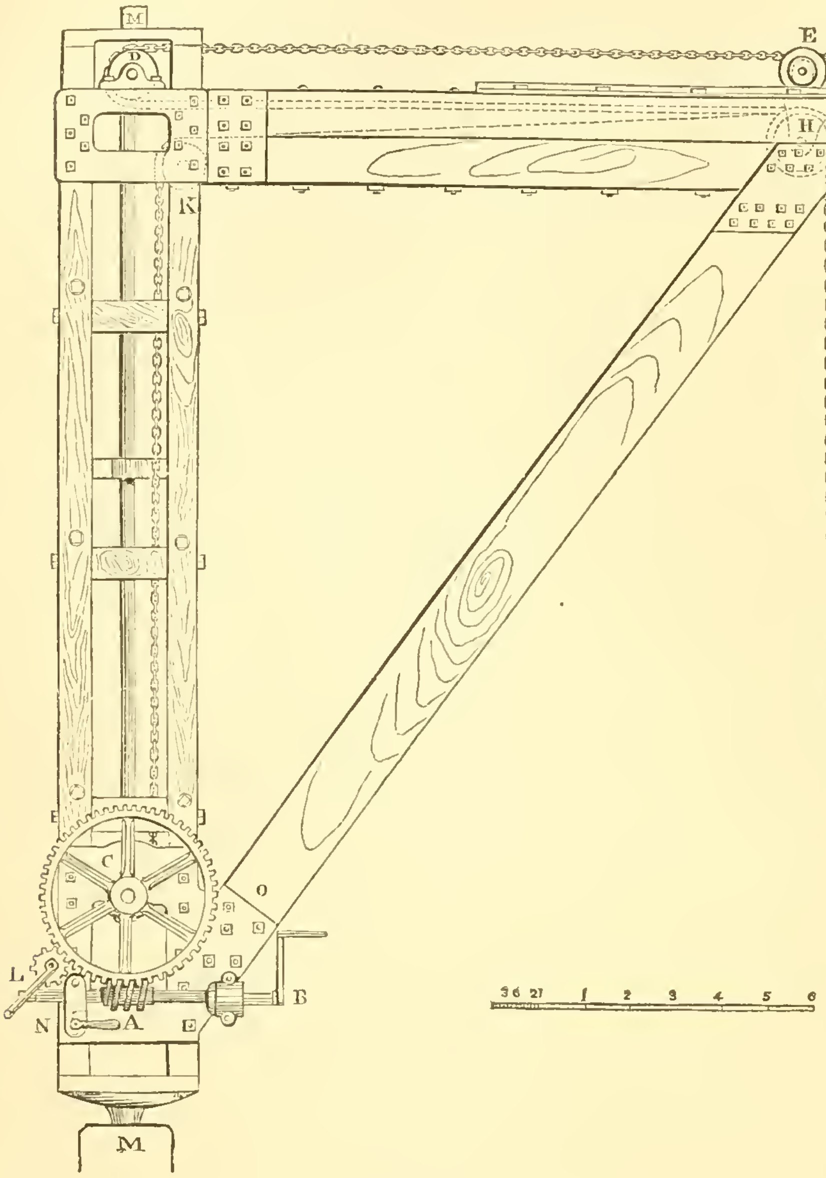

Scale.—1 inch = 8 feet.

on an inclination toward the mast of 20°. By the use of the "Siamese blocks," the stone is moved toward or from the mast and hoisted or lowered with the accuracy requisite for setting fine-cut stone.

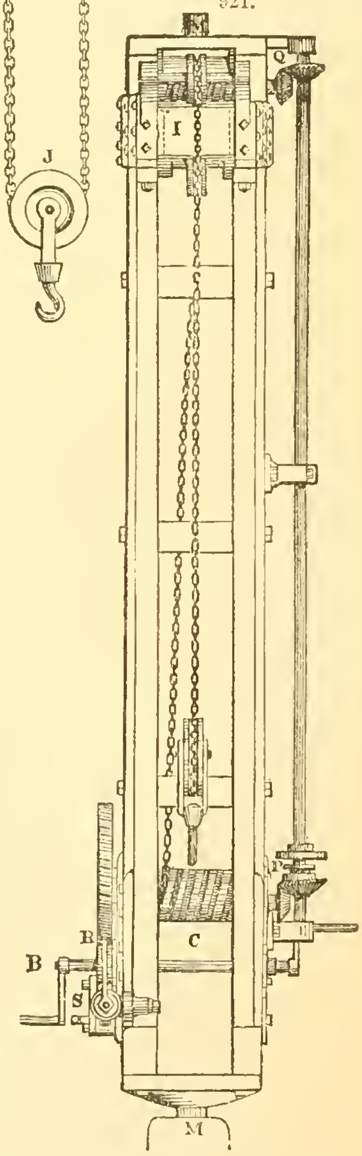
Fig. 920 is a side, and Fig. 921 an end elevation of a *foundry crane*, as constructed at the Lowell

Machine Shop. It is operated as follows: The weight is suspended from the sheave $J$, and is raised by the chain passing over the pulleys $H$ and $K$, and around upon the barrel $C$, either by the boom $A$ or the pinion $L$, according to the weight to be raised. The pulley $H$ is suspended from a carriage supported by the wheels $E$ and $F$, traversing on rails at the top of the cope. Motion in or out is

920.



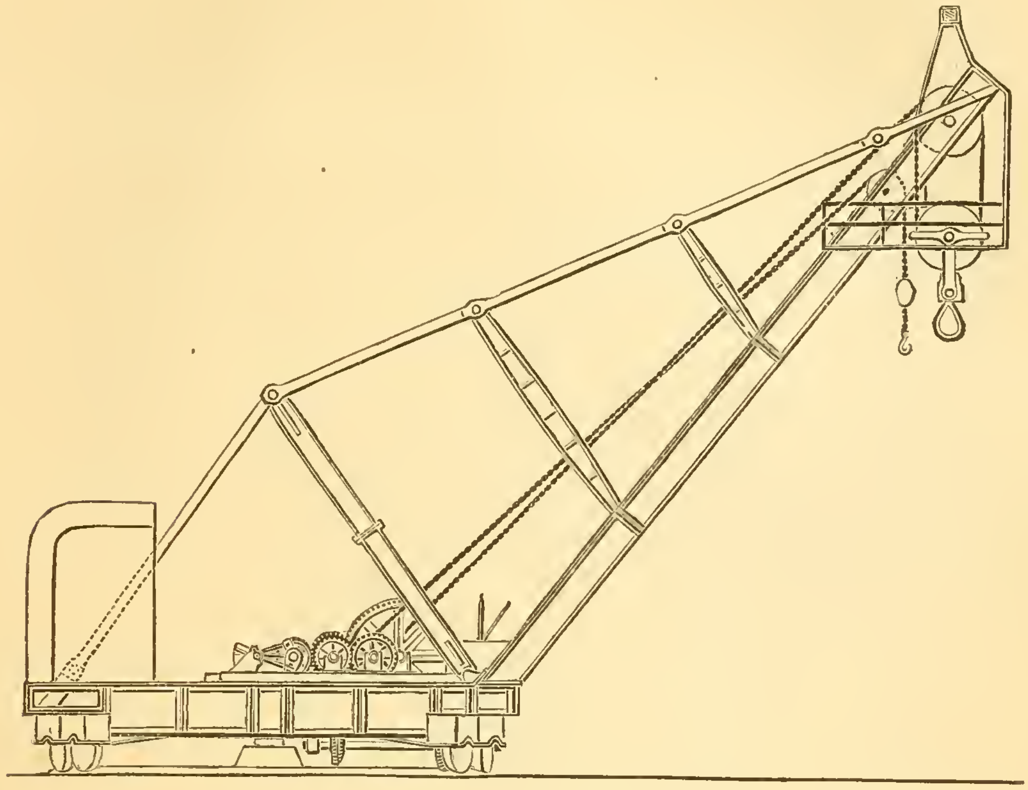

921.




given to this carriage by means of the upright shaft and bevel-wheels at $B$ and $P$, which causes the drum $D$ to revolve, and draw either at the upper part of the chain, which, passing over the pulley $G$, is attached to the outer extremity of the carriage, or at the lower part of the chain, which is fastened to the inner extremity.

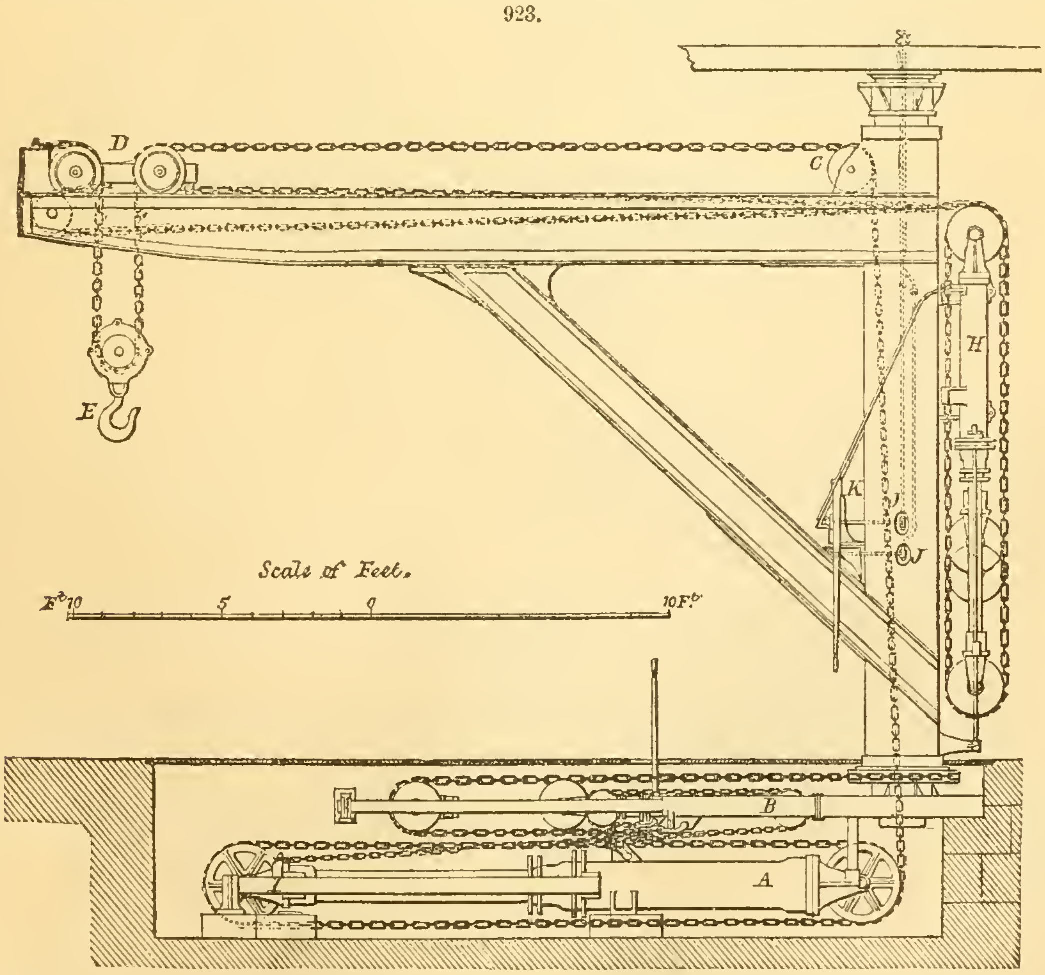
Fig. 922 represents a crane used at Woolwich, England, for handling heavy guns, which is capable of lifting a weight of 85 tons through a height of 60 feet. The jib is of wrought-iron, 55 feet long, and is attached at the bottom to a platform composed of wrought-iron girders mounted upon four pairs of cast-iron rollers, which run along the sweep-plate or roller-path. Two of the pairs have a cogged wheel inside, worked by the hydraulic gear, for revolving the crane within the circle of the roller-path; the other rollers are plain. Each pair of rollers is carried in a cast-iron roller-box, provided with gun-metal bearings for the axles to work in. The roller-path is of cast-iron, and the central pivot or bed, for the crane to work on, of the same material. The latter is bushed with a gun-metal socket for the central pin of the crane, and is connected with the cast-iron summit of the 7-foot screw-pile beneath by four wrought-iron bolts each 3 inches in diameter. The central pin is of wrought-iron, and about 13¾ inches in diameter. It connects the crane to the centre pivot or bed. The platform-girders are floored on the top with timber, to which, and direct to the girders themselves, the bed-plate of the hydraulic engine for winding the chains and revolving the crane is bolted. The stays for the jib are of wrought-iron, and are supported from the jib by other cross-stays, as shown in the engraving. The mainstays are of cast-iron, and trussed together

922.



by diagonal stays of the ordinary character. A wrought-iron platform, lightly constructed, is suspended at the extremity of the jib, for facilitating the means of access to jib-end sheaves. A wrought-iron ballast-box, capable of holding about 100 tuns of gravel or slag ballast, is attached to the plat-

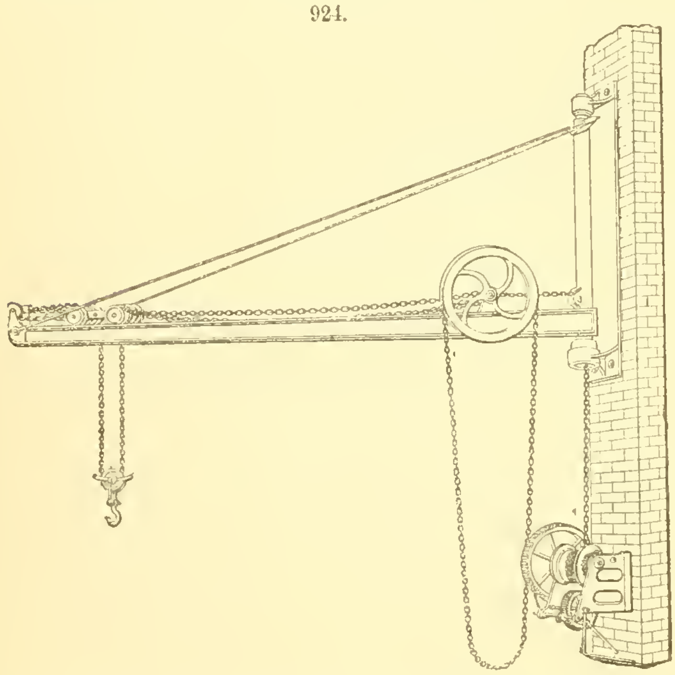
923.




form-girders at the back of the crane, for the purpose of counterweighting the full weight of the load. This counterweight, together with the natural stiffness of the crane, is sufficient to overcome the resistance of the load.

*Hydraulic Cranes* have of late years been introduced with great advantage where water under sufficient pressure is available. The form of hydraulic crane used at Sir William Armstrong's works is represented in Fig. 923. The jib and pillar of the crane are of wrought-iron, and revolve in top and bottom bearings. The crane has three motions, namely, lifting, turning, and traversing, all of which are effected by hydraulic power. The lifting cylinder *A* is made of double power, that is, it will lift slowly or quickly as desired, by a ram and piston arrangement, the highest power being equal to 20 tons; the ram is 11 inches in diameter, and the piston 15½ inches in diameter, the length of stroke being 6 feet 8 inches. The turning cylinders *B* are applied in the usual manner at the foot of the crane pillar, the rams being each 4½ inches diameter, with 5 feet stroke; and both the lifting and the turning cylinders, with their valves, are fixed in a chamber beneath the level of the floor. A three-port slide-valve is used for the two turning cylinders, and mitre-valves for the lifting cylinder. The chain from the lifting cylinder is carried upward through the crane pillar, bending over a sheave *C* at the top of the pillar, and passes successively over the pulleys of the traveling carriage *D* and the running block *E*, and is finally made fast at the extremity of the jib. For the purpose of overhauling the ram of the lifting press, a small press is placed between the two turning presses *B*; and the overhauling action is effected by a chain being attached to the sliding head of the lifting ram at *I*. The pressure in the overhauling press is constant, and its action is therefore equivalent to that of a counterweight; the ram is 4½ inches diameter, with 3 feet 5 inches stroke. For effecting the traversing motion of the load suspended at the hook, the traveling carriage *D* is hauled inward and outward by two presses *H* fixed to the back of the crane pillar, and connected by chains with the traveling carriage; the ram of each press is 5½ inches diameter, with a 4 foot 7 inch stroke. The alternating action of these presses, which is precisely the same as that of the presses *B* used for the turning motion, is regulated by a three-port slide-valve *K* attached to the front of the pillar, with a lever at each side for working it. The water is supplied to and discharged from these presses by two pipes which pass through the top bearing of the pillar, and the connection between the valve and these pipes is effected in each case by a trunnion-joint at *J J*.

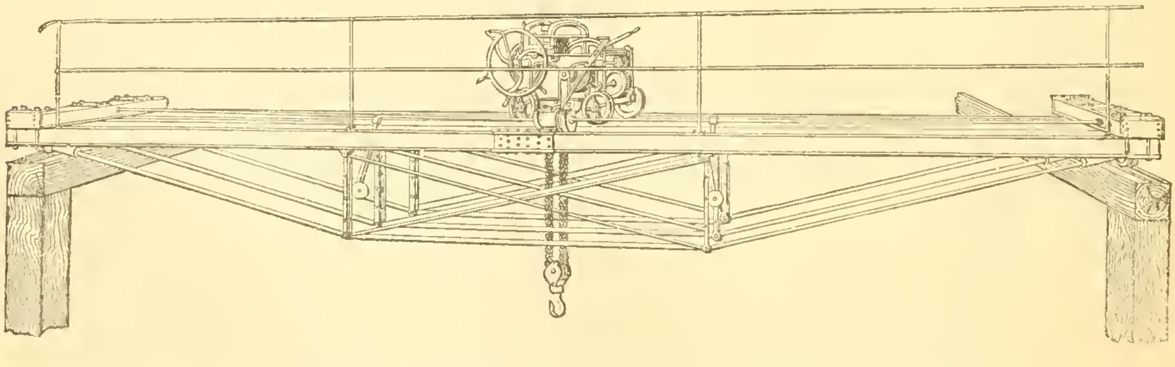
924.



*Wall Crane.*—Fig. 924 shows an example of Appleby's hand-power wall cranes. These cranes may be fixed on any wall, pier, or column of the foundry or forge; and so convenient are they that a traveler may be arranged over them if necessary. In foundries several of these cranes, fixed diagonally with each other, are especially useful for the lighter branches of the work, as the floor in the centre will by this means be entirely free for the heavier duties of the overhead traveler, such as lifting heavy castings or ladles. The traveler is not then wanted for the lighter part of the work, as this is managed by the smaller cranes perhaps more expeditiously than with the heavier ones.

*Overhead Travelers* are made of various designs, the chief points to be observed in their construction being the making of the main girders sufficiently strong for the weight they will be required to support; and in those worked by hand-power, the gearing should be of especially good construction, for it must be borne in mind that the gross weight of both traveler and load has to be moved every time the crane is put into operation. The girders are of several forms, some having timber beams and wrought-iron truss and tie rods, while others are of wrought-iron of various

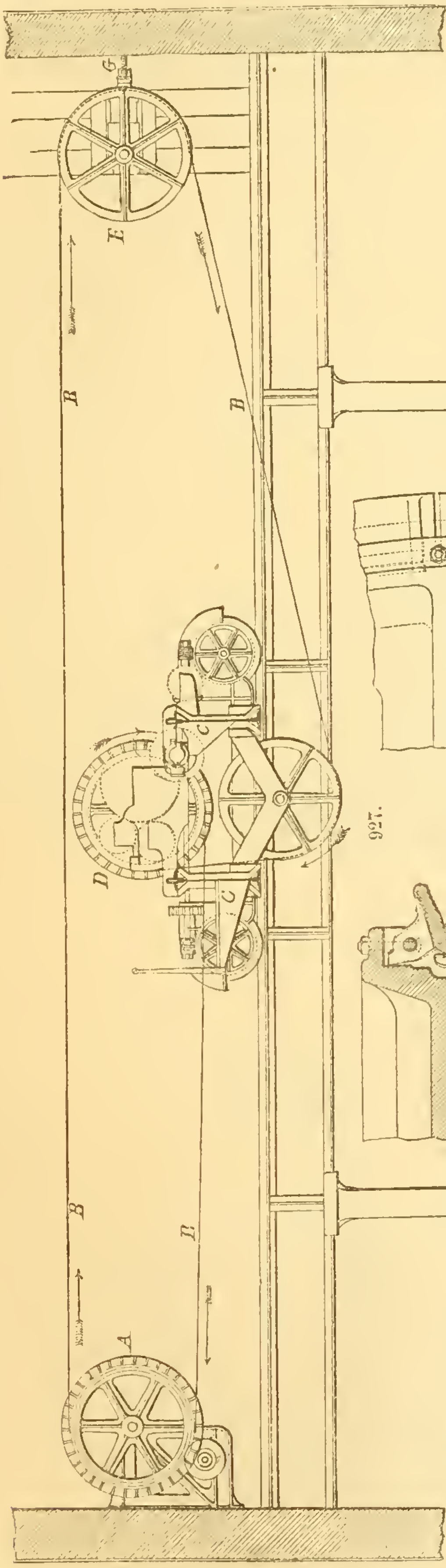
925.



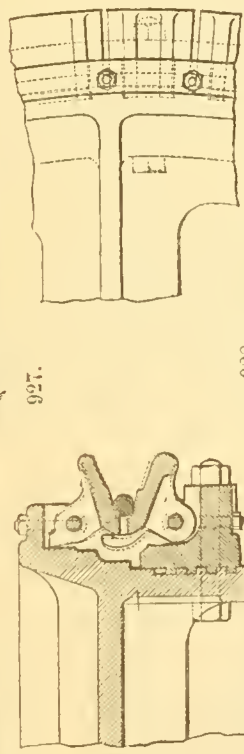
sections. The heavier varieties are fitted with a central or platform girder, which to a great extent supports the weight of the lifting and working gear with its framework.

Fig. 925 shows a traveler with the main and platform girder composed of wrought-iron, rolled in H section and trussed. This form of traveler is frequently used where lightness is required with a

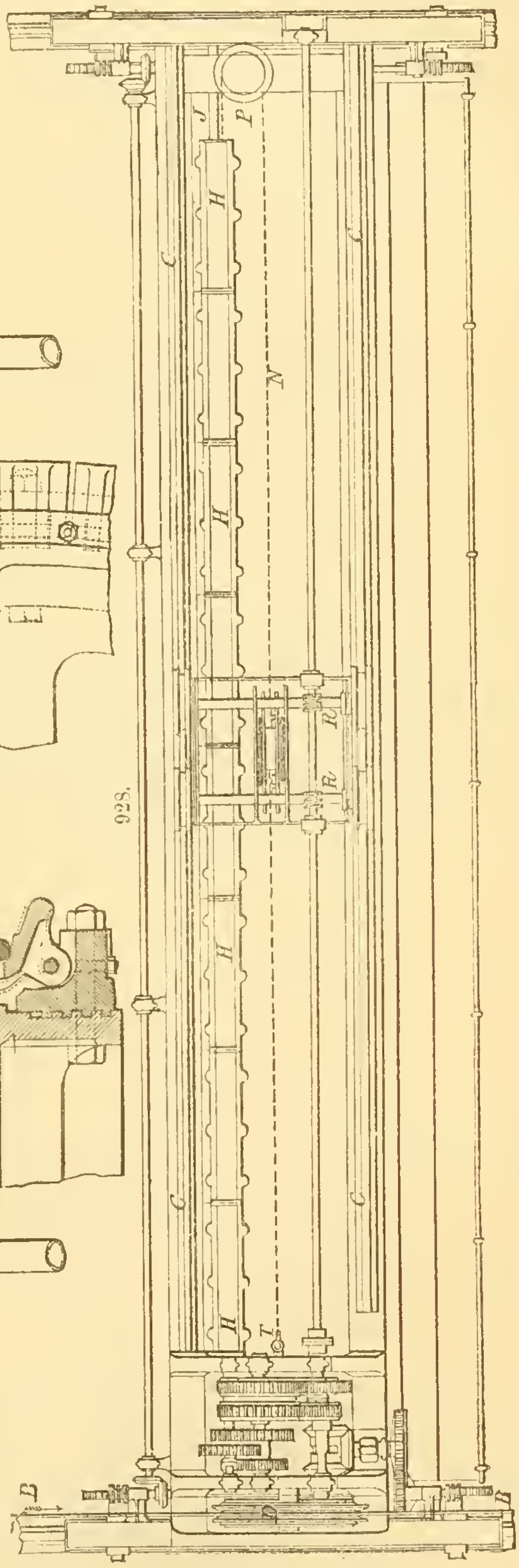
long span. The general arrangement of the crab-gearing is as follows: The lifting gear is single and double purchase, and the power is increased by blocks or chains, the upper sheaves for which are carried in the transom on the top of the side-frames of the crab. The chain-barrel is keyed



926.



927.



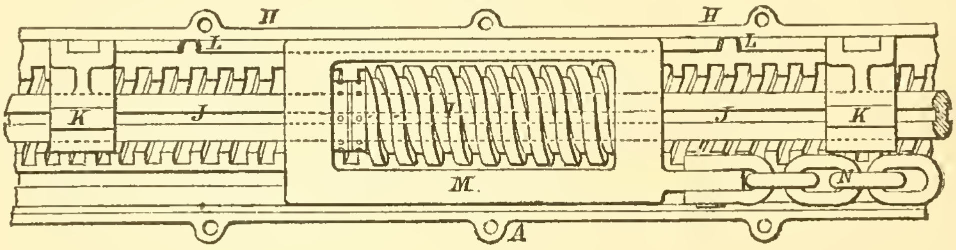
928.

into the large spur-wheel to relieve the shaft from torsion, the ratchet-wheel is cast to the flange of the barrel, and the brake-ring is cast to the spur-wheel; the brake-strap is lined with wood, and fitted with a hand-lever. It will be seen that the two traveling motions are on one centre; the longitudinal motion, being the heaviest work, is given by the crank-handle; the lighter work of the

transverse motion is given by the hand-wheel, and as the attendant can have one hand on it and the other on the crank-handle, a load can be simultaneously moved transversely and longitudinally any short distance required, a condition most favorable to some operations.

Figs. 926, 927, and 928 represent an English wire-rope crane for lifting heavy work ranging from 15 tons downward; it has a span of 40 feet, and traverses a length of 180 feet. The three different motions for longitudinal traverse, cross-traverse, and hoisting are all derived from one endless steel-wire rope, three-quarters of an inch diameter, and weighing 2 lbs. per yard. This rope is driven at a speed of 4 miles an hour, by means of a clip-pulley fixed at one end of the shop, which is driven by belts and gearing from the engine working in the shop. The rope extends the whole length of one side of the shop, going and returning on the same side at the level of the traveler, and passing round a loose pulley at the further end. The rope is entirely unsupported between the two ends, and is not strained tight, but hangs loose with only a slight tension, because the peculiar action of the clip-pulley allows of the whole power being communicated to the rope by the grip of the pulley through half of its circumference, even when the tail-rope is entirely slack. The clip-pulley *A*, Fig. 926, fixed at the end of the shop, is speeded to drive the wire rope *B B* at the rate of 4 miles an hour, and lays hold of the rope with an amount of grip proportionate to the strain thrown upon the

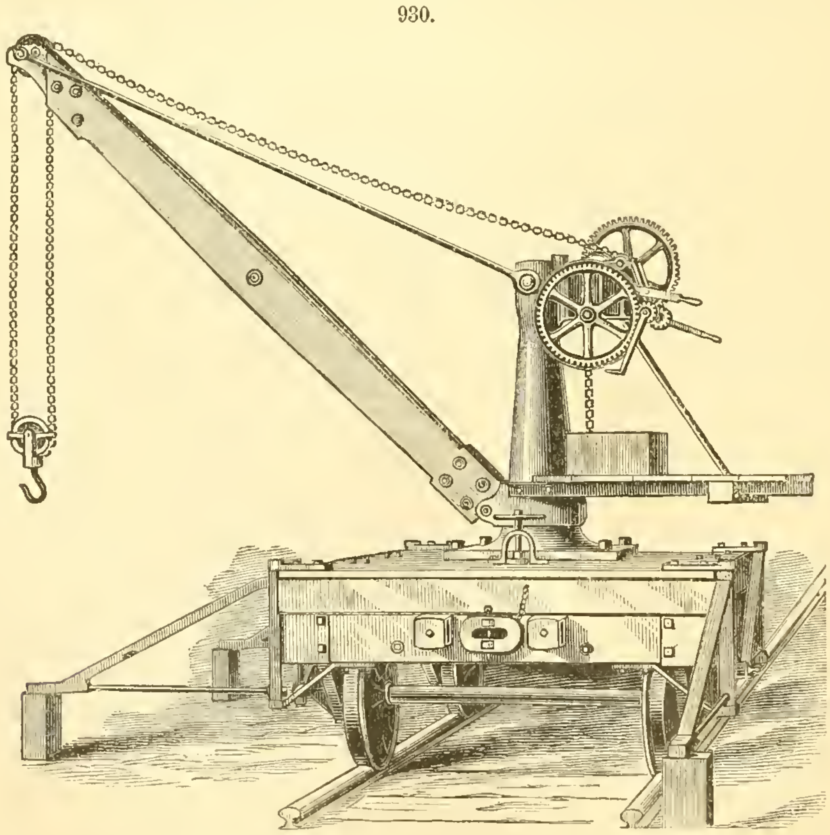
929.




rope by the load, releasing it from its grasp when the rope has passed the centre line. The construction and fixing of the movable jaws or clips round the circumference of the clip-pulley is shown in Figs. 927 and 928. At one end of the traveling platform *C* of the crane is fixed another clip-pulley *D*, of the same size and construction, round which the same wire rope passes, making three-quarters of a turn. The rope then passes on to the further end of the shop, and round the groove-pulley *E* at that end. This pulley is centred in a sliding frame provided with an adjusting screw *G*, for tightening up the rope to any tension required. It has not been found necessary to have any sliding weight attached to this frame, for variable tension of the rope.

The lifting gear consists of a very long cast-iron nut or screwed barrel *H H*, extending nearly the whole length of the traveler, as shown in the plan, Fig. 929; and inside the barrel works a short

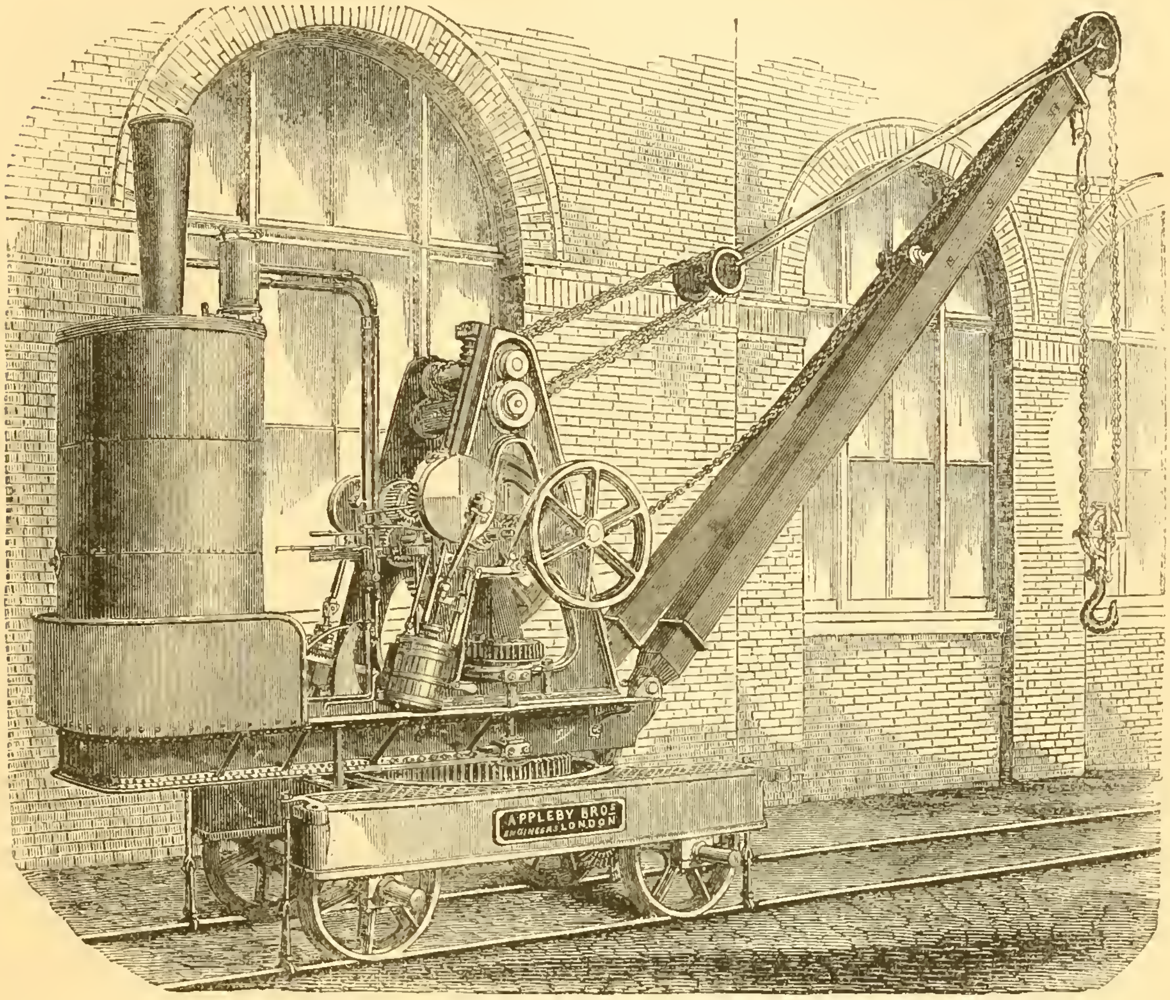
930.



screw *I*, sliding on two feathers upon the long shaft *J J*, which is driven by a friction-clutch from the clip-pulley *D* on the traveler, so that by the revolution of the shaft the screw is traversed along with the barrel. The long driving-shaft *J* is supported at intermediate points of its length by the two sliding brass steps *K K*, sliding along freely with the barrel *H*, and kept apart from each other at

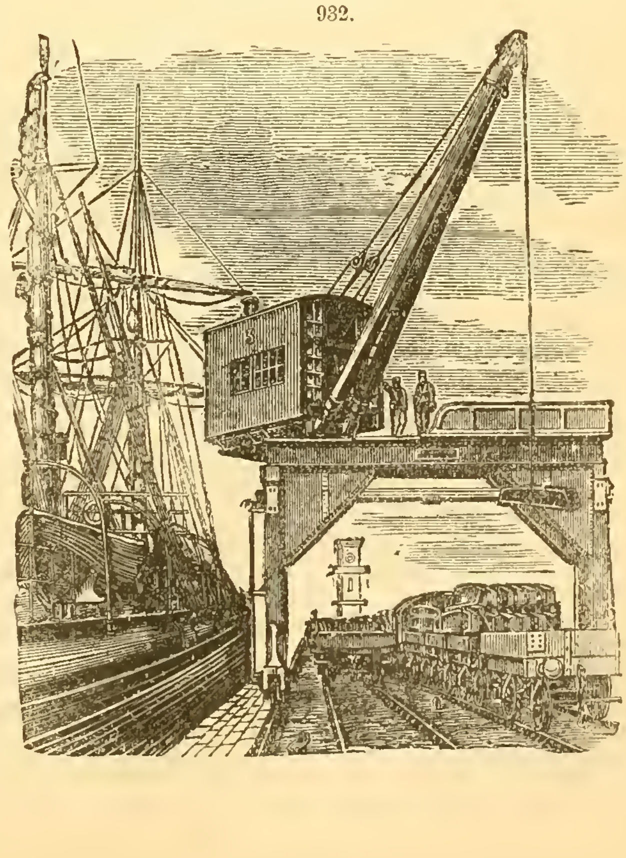
the distance of half the length of the barrel by the rod *L;* by this means the shaft *J* is never left unsupported for more than half its length. One end of the hoisting-chain being attached to

931.




the screw-frame *M*, Fig. 929, the chain *N* passes along through the inside of the barrel *H*, round a pulley *P* at the further end of the traveler; then over a pulley on the cross-traversing carriage *R*, Fig. 927, down to a snatch-hook, and up again over a second pulley on the carriage *R;* and the end is attached to the nearest extremity of the traveller at *T*. The crane has two speeds for the lifting gear, one being at the rate of 6 feet per minute, the other at the rate of 3 feet per minute; and at the latter speed the crane is calculated to lift 15 tons.

932.

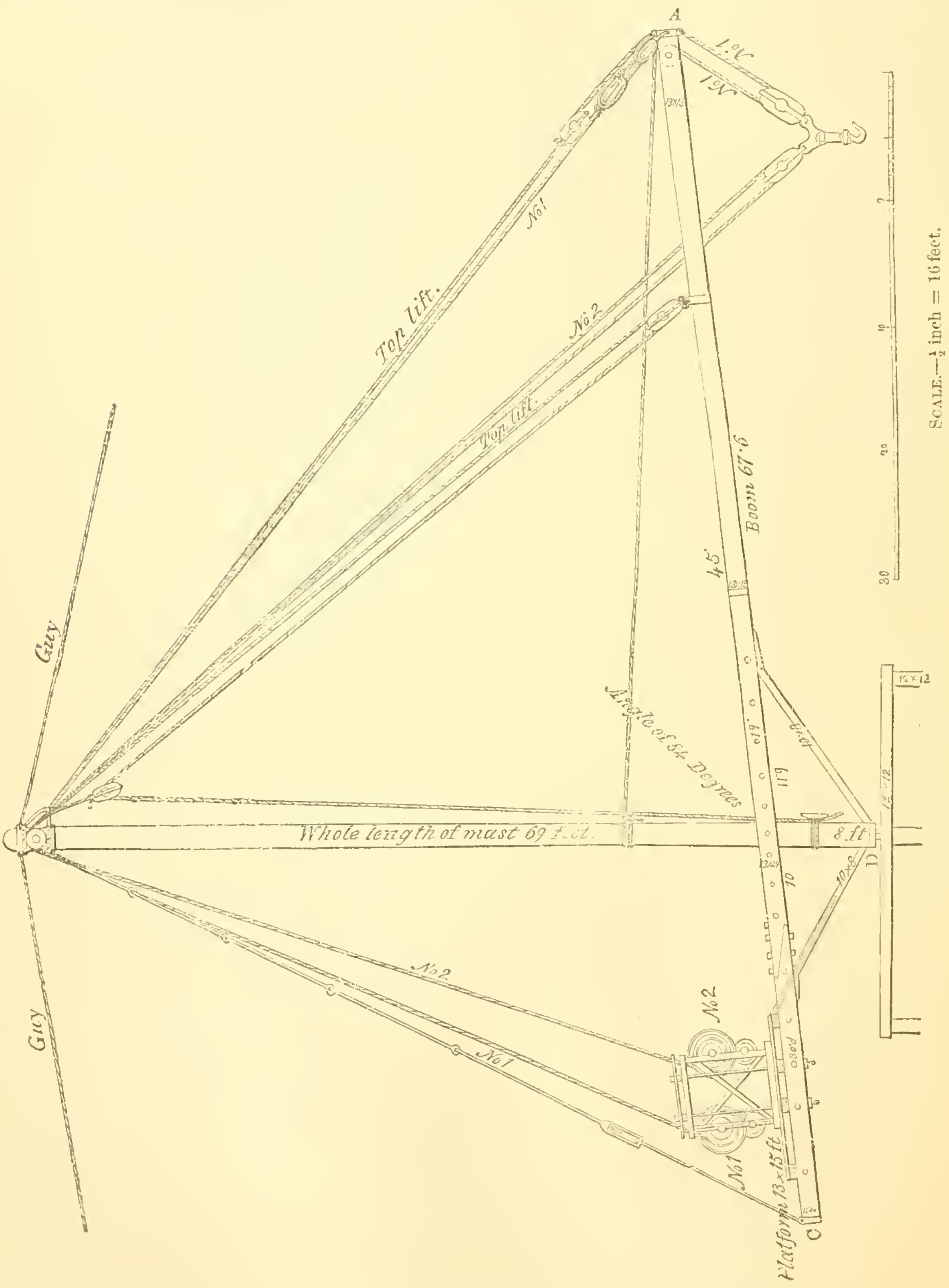


*Traveling Cranes.*—Fig. 930 represents a portable crane constructed by Messrs. W. Sellers & Co. It is designed to accompany goods cars, and to be used in loading and unloading freight at way stations on railways. The chain, passing over sprocket-wheels, is coiled in a box on the platform. This arrangement permits the use of a very much longer chain than is admissible when wound on a drum in the ordinary manner, and diminishes the size, parts, and amount of machinery required in the hoisting gear. The swinging gates serve to spread the base of the car in any required direction when the crane is in use. These gates ordinarily lock to the side of the car.

Fig. 931 represents a large 7-ton steam traveling crane built by Messrs. Appleby of London. The engines are carried on a base-plate which rotates on friction-rollers. The boiler and machinery serve as a counterbalance to the weight to be lifted. The work is done with a pair of

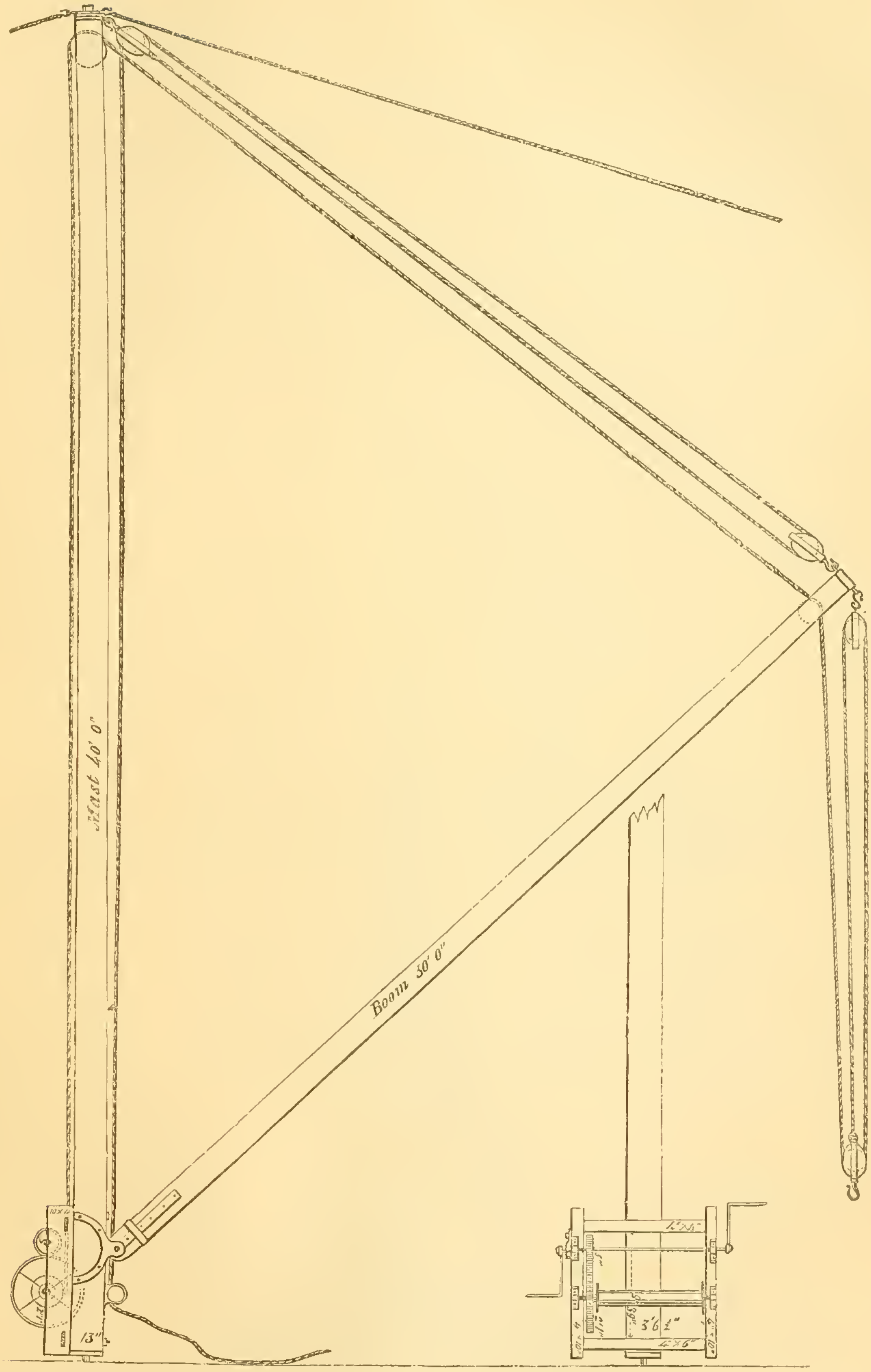
direct-acting steam-cylinders placed slightly on the incline, one outside each side-frame, the crank-pins being fitted into a pair of balanced disk-plates. In addition to the usual lifting and turning motions, each crane has a neat arrangement for traveling by steam, and for altering the radius of the jib by the same agency. The engine-shaft between the side-frames carries a bevel-wheel, made fast or loose on the shaft by means of a toothed clutch, for driving an oblique worm-shaft gearing into a tangent wheel on the derrick-chain barrel for raising or lowering the jib, the worm-wheel securely locking the wheel in any position. A broad spur-wheel is geared on the crank-shaft, and works a narrow wheel below it on a weigh-shaft, which has a small crank-pin at each end equal in length to the stroke of the slide-valves. The narrow wheel can be moved by a hand-lever laterally about 4 inches on a spiral feather, thus reversing the valves for running the engines in either direc-

933.




tion. A pair of spur-wheels are placed on the left side of the crank-shaft, and gear into wheels on the countershaft below. One pair of these wheels are of equal and the other of unequal diameters, and either pair can be made drivers by means of a double-toothed clutch. Provision is made for working the crane by hand if necessary through the shaft, which also carries a set of bevel-wheels

934.



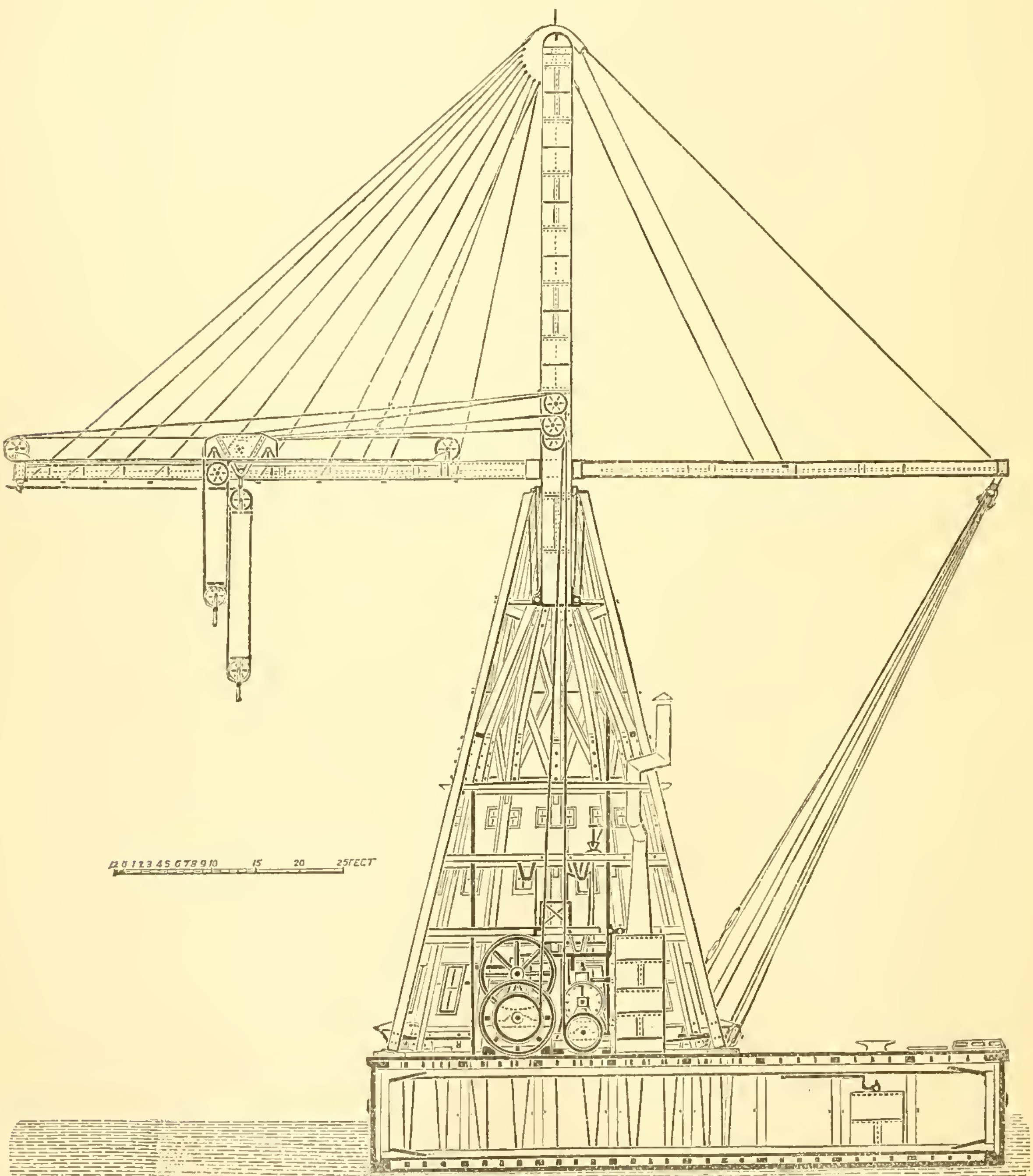

and double friction-cones for driving the slewing and traveling motions. As this shaft has two speeds communicated to it from the engine-shaft, it will impart two speeds to the slewing and traveling motions. The motion from this set of wheels is transmitted through a train of wheels to the spur-wheel on the column, which is twice the depth of the pinions gearing into it. The pinions are placed at different heights, so that the slewing pinion clears the pinion driving the traveling gear, which is fixed. To travel the crane, the body is fixed to the carriage, and the wheel revolving on the crane-post drives the traveling mechanism. The friction-cones are operated by an eccentric lever, and can be thrown into contact while the engine is running, the jib being put in motion gradually. On the cones being reversed, they act as a brake and arrest the motion of the jib. A pinion sliding on a feather in and out of gear, with a spur-wheel on the barrel-shaft, conveys the lifting motion

from the counter-shaft. This pinion is withdrawn for lowering, and the descent of the load is controlled by a strap-brake worked from a foot-lever, which is fitted with a pawl and ratchet, so that the load can be left suspended at any point of its descent. As the slewing motion can be put into action through the cones while a load is being raised or lowered, considerable saving of time is effected. The speeds of working are in direct relation to the loads. As many as 60 or 70 loads may be lifted and turned around in an hour with the quick speed.

Fig. 932 represents an overhead traveling crane as arranged for the loading of vessels along river-fronts and docks. As constructed at the docks of Middlesborough, England, the traveling stage or gantry of each crane has a span of 23 feet from centre to centre of the rails. The clear height is 17 feet 6 inches, and the traveling wheels are 12 feet apart. The crane and the whole of the substructure is designed for a working load of 5 tons at the maximum radius of 21 feet.

Derricks.—Fig. 933 represents a common form of derrick used for the setting of small stones. The mast is supported in upright position by radial guys, made fast severally to posts set firmly in the ground. The weight to be raised is attached to the lowest block, which is suspended by means of another block to the end of the boom. The rope passes over the pulley or sheave in or on the boom, and thence over another near the top of the mast; thence passing down parallel to the mast, it is attached to a barrel or drum, and can be taken up or let out by means of a gear and pinion and

935.




crank, thereby raising or lowering the weight. The boom can be raised or lowered by means of the rope at the bottom of the mast, which is passed two or three times round a small fixed cylinder, and is united to the end of the boom by a system of blocks. By the slacking of this rope, the boom may be lowered while the weight is suspended, which enables the workmen to take up the stone at

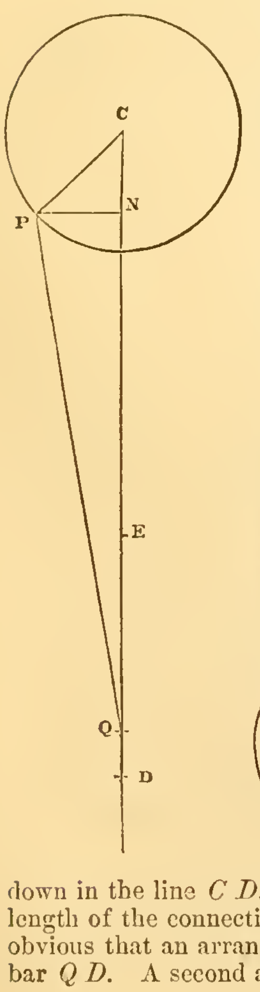
one distance from the mast, and lay it at another more remote. The machine is swung into position by a small rope attached to the end of the boom or to the weight itself.

Fig. 934 represents Savage's derrick as improved by Mr. McAlpine, and used at the Brooklyn Dry Dock for the laying of the heaviest stone. It differs somewhat in its arrangement from the simple machine already described. It will be seen that the hook for the suspension of the weight is supported by two blocks. By tracing the position of the rope No. 1, it will be seen that by it the right-hand one of these blocks can be raised or lowered by means of the crank, pinion, gear, and barrel No. 1 of the crab, at the opposite end of the boom; in a similar way, the left-hand block is raised by rope No. 2. Thus it will be seen that, by the winding up of rope No. 1 on the barrel, a motion upward and outward is given to the suspended weight, whereas by the winding up of No. 2 the weight is raised upward and onward. Again, if rope No. 1 alone be slackened, the weight is lowered outwardly. By these means the stone may be deposited at any spot within reach of the boom.

In Fig. 935 is represented the large floating derrick used for lifting blocks of *béton* weighing as much as 100 tons, in the construction of the stone piers for the city of New York. The float is of rectangular form, one side being 75 feet, the other 70 feet; its depth is 13 feet. It is stiffened by 16 trusses made similar to the well-known Howe truss. The tower which carries the ring-post and booms is made of twelve pieces of Georgia pine, 14 by 14 inches at the lower ends, 63 feet 3 inches in length, and 12 by 12 inches at the upper end; these legs are stiffened by struts and braces. The lower ends of these legs are fastened into a heavy cast-iron circle. At their upper extremities the legs are brought close together, and are held by a casting of circular form, to which they are bolted. This casting is made with a recess which is filled with spherical rollers, which rest against a casting fitted to the ring-post, so that its lateral pressure where it passes the tower causes but little friction. The front or hoisting boom of the derrick consists of two plate-iron box girders 22 inches deep by $9\frac{3}{4}$ inches wide; the upper and lower members of these girders are of channel iron three-fourths of an inch thick; the side plates, which are riveted to them, are three-eighths of an inch thick. All the rivet-holes are drilled. These girders are spaced 24 inches asunder, and are held in position at the ring-post ends by being inserted in deep sockets formed in a heavy casting which encircles the post. The boom is supported by 18 diagonal rods $2\frac{1}{2}$ inches in diameter, made of iron. These converge near the top of the ring-post, and are secured to it. The following are the chief dimensions of the structures: Length of float 71 feet, breadth 66, depth 13; length of hoisting boom 60 feet 3 inches, of back boom 50 feet $3\frac{1}{8}$ inches; length from end to end of boom, 110 feet $6\frac{1}{8}$ inches; height of tower, 62 feet 3 inches; height of ring-post above tower, 49 feet 8 inches; total length of ring-post, 62 feet; height from bottom of float to top of ring-post, 127 feet 3 inches.

CRANK. A crank is a lever or bar movable about a centre at one end, and capable of being turned round by a force applied at the other end; in this form it has been used from the earliest times as a handle to turn a wheel. When the crank is attached by a connecting-rod to some reciprocating piece, it furnishes a combination which is extremely useful in machinery.

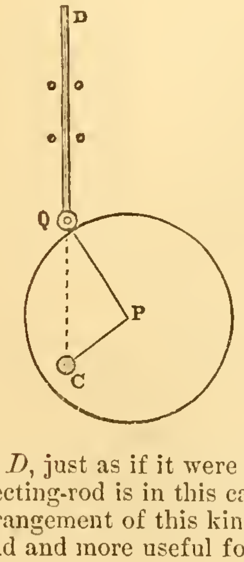
936.



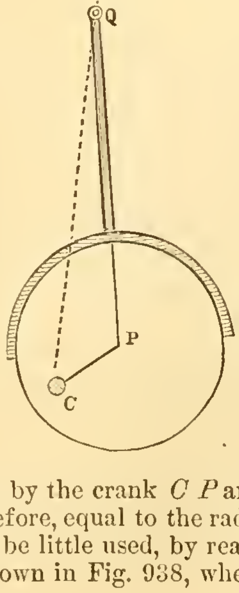

Let $C P$, Fig. 936, represent an arm or crank centered at $C$, and connected by means of a link or connecting-rod, $P Q$, with a point $Q$, which is constrained to move in the line $C E D$. The formula $C Q = a \cos C + \sqrt{b^2 - a^2 \sin^2 C}$ gives the position of $Q$ for any given position of the crank $C P$; $a$ being the length of the crank, $b$ the length of the connecting-rod, and $C$ the crank-angle $P C D$. The space $D E$ is called the throw of the crank.

The *eccentric circle* supplies a ready method of obtaining the motion given by a crank and link. In Fig. 937, a circular plate movable about a centre of motion at $C$ imparts an oscillatory movement to a bar $Q D$, which is capable of sliding between guides in a vertical line $D Q$, pointing toward $C$. Since $P Q$ remains constant as the plate revolves, it is evident that $Q$ moves up and

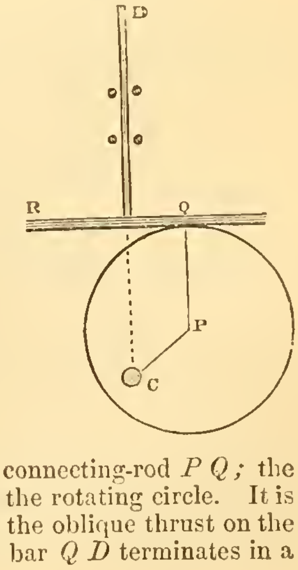
937.




938.




939.

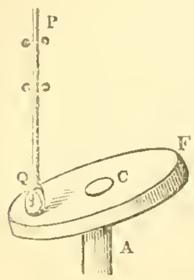



down in the line $C D$, just as if it were actuated by the crank $C P$ and the connecting-rod $P Q$; the length of the connecting-rod is in this case, therefore, equal to the radius of the rotating circle. It is obvious that an arrangement of this kind would be little used, by reason of the oblique thrust on the bar $Q D$. A second and more useful form is shown in Fig. 938, where the bar $Q D$ terminates in a

half hoop which fits the circle. The form usually adopted in practice is derived at once from this. A circular plate is completely encircled by a hoop, to which a bar is attached.

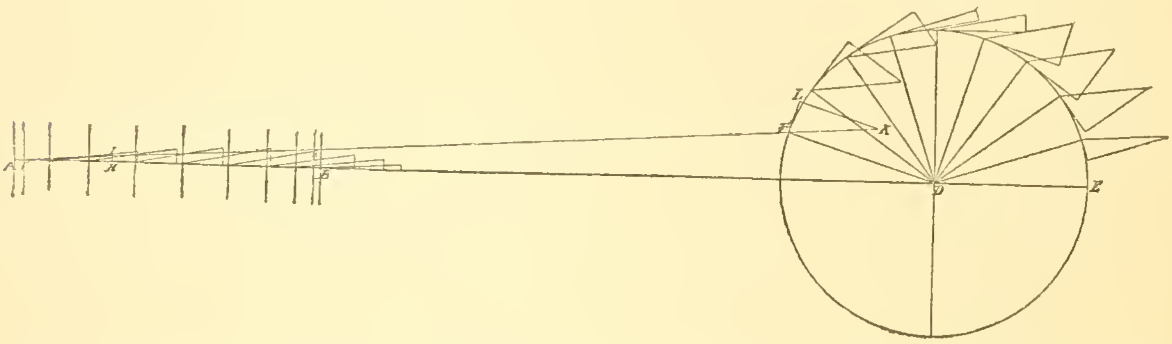
The *crank with an infinite link* is shown in Fig. 939. Suppose the roller at $Q$ to be replaced by a cross-bar $Q\,R$, standing at right angles to $D\,C$; as the circle revolves, it will cause the bar to reciprocate, $C\,P$ will remain constant, and $P\,Q$ will always be at right angles to $R\,Q$, and will therefore remain parallel to $C\,D$ in all positions. The crank with an infinite link also appears under the guise of a *swash-plate.* Here a circular plate, $E\,F$, Fig. 940, is set obliquely upon an axis, $A\,C$, and by its rotation causes a sliding bar $P\,Q$, whose direction is parallel to $A\,C$, to oscillate continually with an up-and-down movement, the friction between the end of the bar and the plate being relieved by a small roller.

940.



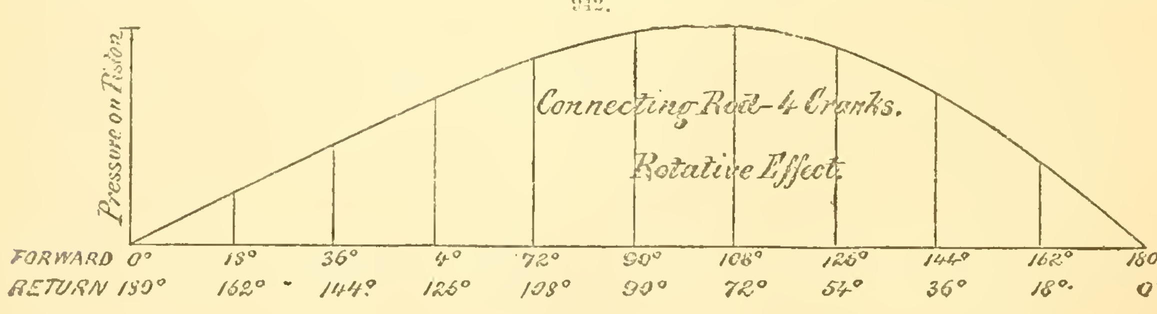

In the reciprocating engine, which is the ordinary form of construction, the rectilinear motion of the piston is transmitted through a connecting-rod to the crank, and there changed into rotary motion. It is evident, therefore, that the two ends of the connecting-rod travel different distances in the same space of time, one end describing a path which is equivalent to the diameter of a circle in which the other end of the connecting-rod passes through half a revolution in the same time; so that the distances described by the two ends are as 1 to 1.5708, this being the ratio of the diameter to the semi-circumference of a circle. Let the circle in Fig. 941 represent the path described by the

941.

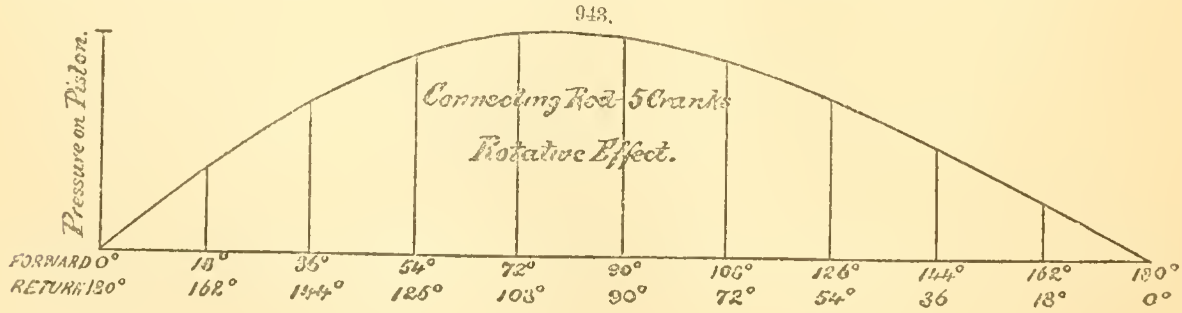



centre of the crank-pin in one revolution of the engine. Suppose $D\,F$ is the position of the crank, and $G\,F$ the position of the connecting-rod, when the piston is at the point $G$ in the line $A\,B$, which represents the stroke. If the pressure on the piston at this point is represented by the line $G\,H$, by drawing a perpendicular $H\,I$ to the line $A\,B$ at the point $H$, $G\,I$ will be the effect of the given pressure in the direction of the connecting-rod, and $F\,K$, equal to $G\,I$, will be the force transmitted by the connecting-rod from the piston to the crank-pin. But the only part of this force which can produce motion in the crank is that which acts tangentially to the circle at $F$, or in a perpendicular direction to the crank $D\,F$. To determine the magnitude of this tangential force, draw $K\,L$ parallel to the position of the crank, and $F\,L$, drawn perpendicular to the crank, will be the tangential force required. In Fig. 941 the semi-circumference is divided into 10 equal parts, and the tangential

942.



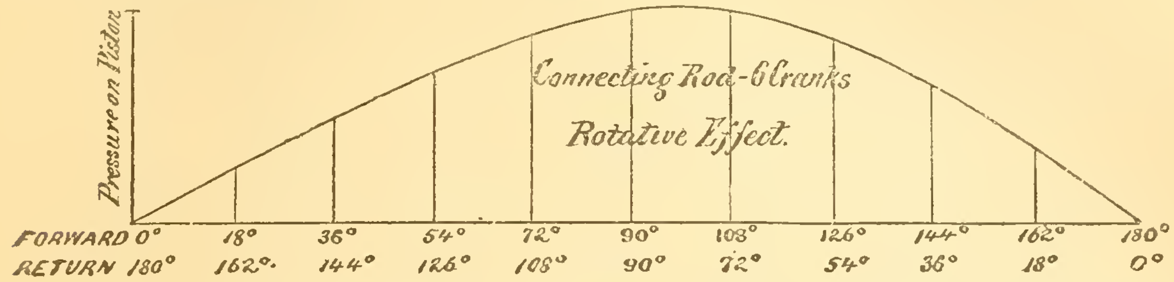

943.




pressure is determined for each in the manner indicated above. If the pressures so determined are then laid off on perpendiculars to a base line representing the path of the crank-pin, dividing it into 10 equal parts, the extremities of the perpendiculars can be connected by a curve, which gives the rotative effect at every point of the revolution. This is illustrated in Figs. 942, 943, and 944, which are diagrams of rotative effect for connecting-rods of different lengths. It will be seen that the

rotative effect is unevenly distributed through the two quadrants of the semi-revolution, on account of the angularity of the connecting-rod, and that this irregularity diminishes as the connecting-rod is lengthened. With a connecting-rod of infinite length, representing the case in which there is no

944.




angularity of connecting-rod, as in the yoke connection, there is no irregularity in the two quadrants. It will be seen that with any length of connecting-rod the rotative effect at any point is generally less than the corresponding pressure on the piston; and that at the ends of the stroke, when the crank is "on the centre," the rotative effect is zero. From these facts some have supposed that there is a loss of power in its transmission by this form of connection; but, as has frequently been shown, this opinion is not well founded. Power, it must be remembered, cannot be produced without motion; and since the crank-pin travels through a larger distance than the piston, it requires a less mean pressure to give the same power as is exerted by the piston. The reader who desires to investigate this subject more fully will find discussions in Scott Russell's "Treatise on the Steam Engine;" in the *Scientific American* for Aug. 22, 1874; and in the *Iron Age*, Sept. 25, 1873.

In the year 1849 the Society of Arts offered a prize "for the best collection of diagrams (with explanations) to illustrate the action of the forces on a crank or cranks turned from a horizontal direct-action steam cylinder or cylinders; the effect of various proportions of connecting-rods, and degrees of expansion of steam, being shown." The following diagrams were communicated to the Society in accordance with their invitation, by W. Pole, C. E., and obtained the silver Isis medal.

The varieties of expansion taken in these diagrams aie three, viz.:

Steam admitted during the whole stroke (Nos. 4, 5, 6).
" " half the stroke (Nos. 7, 8, 9).
" " one-fourth the stroke (Nos. 10, 11, 12).

The varieties of length of connecting-rod have also been taken at three, viz.:

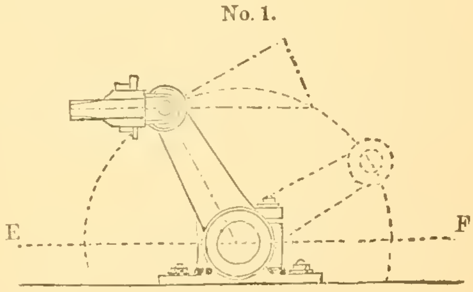
Connecting-rod indefinitely long, supposed to act always in parallel directions (Nos. 1, 4, 7, 10).

Connecting-rod five times the length of crank, which may represent about the ordinary length (Nos. 5, 8, 11).

Connecting-rod three times the length of crank, or about the shortest made (Nos. 6, 9, 12).

Diagram No. 1 is explanatory of the action of the forces in the transmission of the power from the piston to the crank, for an indefinite length of connecting-rod. The piston-rod is shown by the long dotted line.

No. 1.




The object of diagrams Nos. 4 to 12 is to exhibit the values and variations of the forces at the beginning and end of the engine; i. e., the pressure of steam on the piston, and the force turning the crank round.

Each set of these diagrams contains a figure showing the pressure on the piston at all points of the stroke, on the plan of rectangular coördinates; the abscissa representing the space passed over by the piston, and the ordinate the corresponding pressure. Thus, when the piston has moved from 0 to $x$, No. 7, or $\frac{7}{10}$ of the whole stroke, the steam-pressure upon it is represented by the line $x\,y$. The scale given under the left-hand figure, in Nos. 4, 5, 6, and which also applies to Nos. 7 to 12, shows the position of the crank corresponding to any given position of the piston: thus, in No. 6, it is seen by inspection that when the piston has passed through $\frac{5}{10}$ of its course, the crank has passed through about 81° from the dead point, and so on.

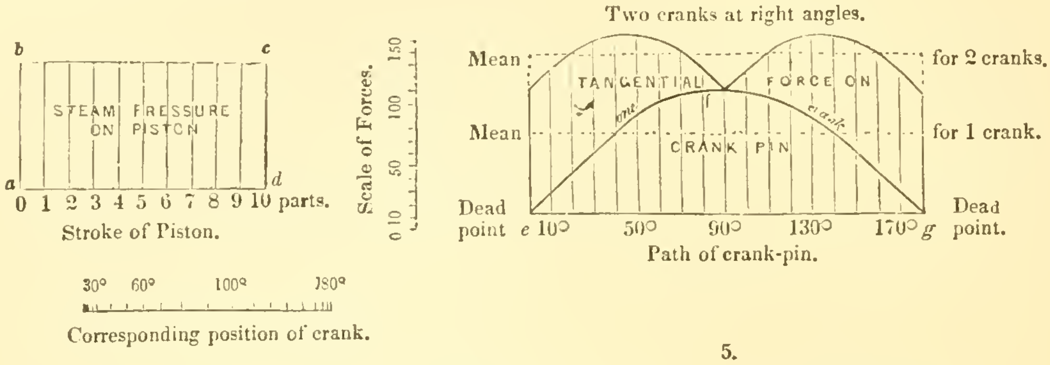
The right-hand figure in each diagram represents the tangential or working force acting on the crank-pin at every point of its semi-revolution from $E$ to $F$, Nos. 1, 2, and 3. The curve of this figure is also laid down by rectangular coördinates; the path of the crank-pin (reduced to a straight line) forms the line of the abscissa, while the ordinates express the corresponding forces. Thus, in No. 5, when the crank-pin has moved from 0 to o, or 120° from the dead point, the tangential force, tending to turn it round, is represented by the line o o. The additional scale under this diagram shows the position of the piston corresponding to any given position of the crank; thus, in No. 5, when the crank is at 140°, the piston has moved through $\frac{9}{10}$ of its stroke, and so on. The lines representing the forces are measured by a scale, which is appended to diagram 4. The pressure of the steam upon the piston, while the steam-valve is open, is made = 100 on the scale; and the ratio of any other force to this pressure is therefore easily ascertained by simple measurement.

In No. 4, the connecting-rod is supposed indefinitely long; the pressure on the piston is uniform at 100. The tangential force on the crank-pin begins at 0 when the crank is at the dead point, increases to 100 when it arrives at 90°, and diminishes again to 0 in the same ratio as the increase. The mean value of the force, throughout the semi-revolution, is = 63.6, which × the space passed

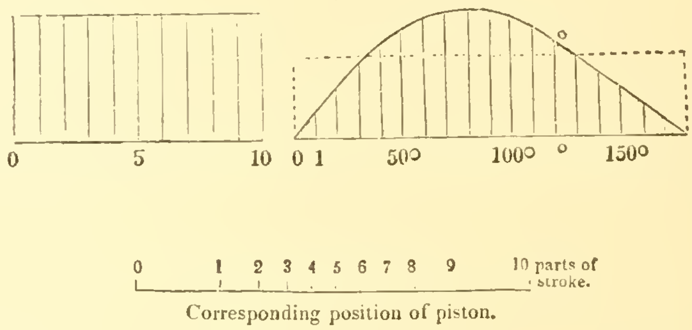
through by the crank-pin is exactly = the pressure on the piston × the length of its stroke; or, in other words, the area of the figure *e f g* = the parallelogram *a b c d*. The result is in accordance with the principle of "conservation of *vis viva*," by which we know that (neglecting friction) the amount of power or work given out at the crank-pin is equal to that performed by the steam on the piston.

In No. 5 is seen the effect of the connecting-rod being made five times the length of the crank. Here the tangential force, commencing at 0, arrives at a maximum value of about 102 when the crank has passed through about 80°.

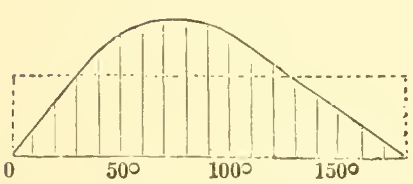
4.




5.




6.

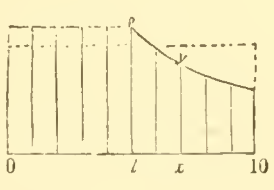



In No. 8, where the connecting-rod is three times the length of the crank, the tangential force arrives at a maximum value of about 106 when the crank has passed through about 75°.

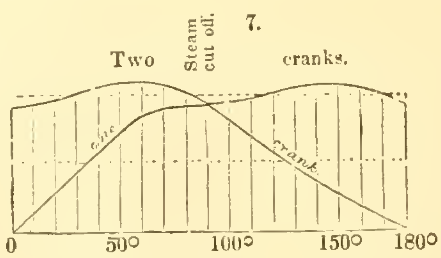
It will be perceived, however, that these variations make no difference in the mean force throughout the whole figure; the effect of the connecting-rod being merely to vary in a slight degree the distribution of the force over the path of the crank-pin, without affecting the total amount of power conveyed to it by the machinery. The comparative merits of long and short connecting-rods, in other points of view, involve considerations which it would be out of place to introduce here.

The return stroke, or the other semi-revolution of the crank, does not exactly correspond with the figures shown in diagrams 5 and 6, owing to the reversed condition of the connecting-rod. The nature of the variation will be seen in No. 6*, where the tangential force is shown for an entire revolution of the crank. It will be observed here that the force at 10° (commencing at $A'$) corresponds with that at 350°, at 60° with 300°, and so on.

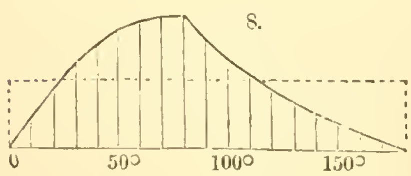
7.



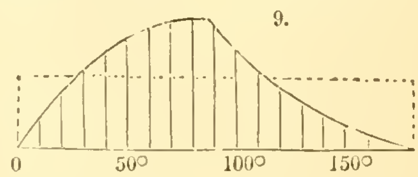

7.




8.




9.



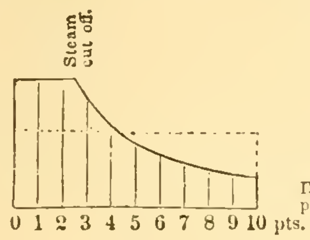

Nos. 7, 8, 9 show the effect of cutting off the steam at half the stroke. Here the mean pressure on the piston is = 84.6, and the mean tangential force on the crank-pin is = 54, the equality between the areas of the right- and left-hand figures being still preserved. The power of the engine is diminished in the proportion of 1000 : 846, although the economy is much increased, as is well known.

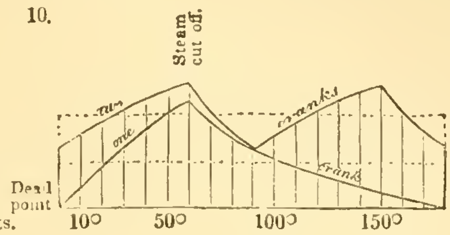
Nos. 10, 11, 12 show the effect of cutting off the steam at one-fourth of the stroke. Here the mean pressure on the piston is = 59.6, the mean tangential force is = 38, and the power of the engine is reduced from 100 to 59.6.

Nos. 9* and 12* show the values of the tangential force through an entire revolution of the crank, in the cases above alluded to under corresponding numbers.

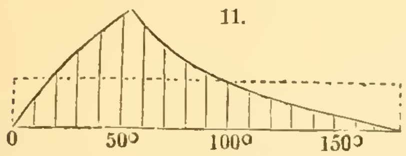
The combined action of two engines, with cranks fixed at right angles with each other, is shown in six cases out of the nine previously described; namely, with three variations in the degree of expansion, and two in the length of connecting-rod. The curve of tangential forces is laid down for

10.

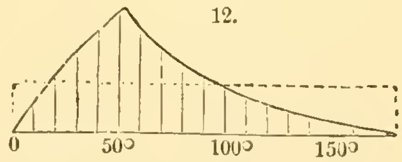



11.

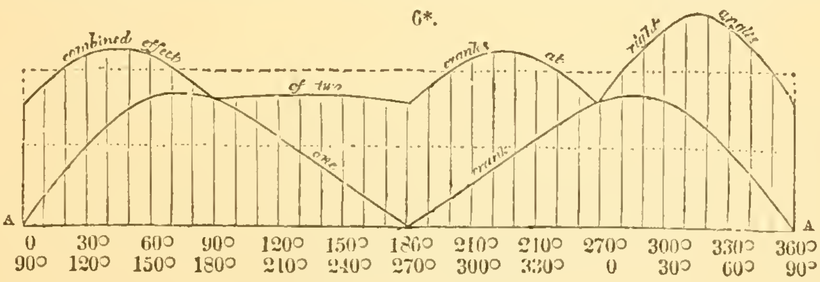



12.



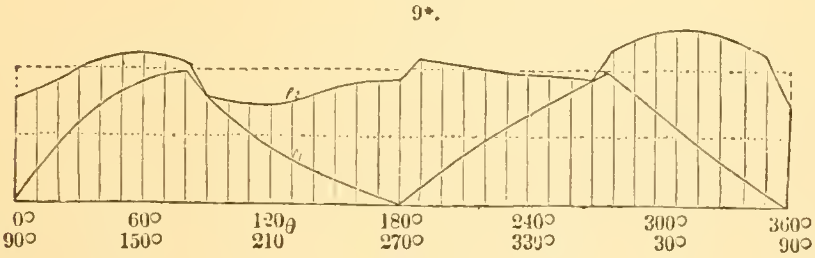

two cranks in diagrams 4, 7, 10, 6*, 9*, and 12*; in the three former for half a revolution (the other half being precisely similar), and in the three latter for a whole revolution of the crank. It is presumed that these figures will be understood without any further description. As an example: at $\theta$, No. 9*, one crank is supposed to have traveled 130° from the dead point $E$, No. 3, the tangential force on it being expressed by the line $\theta\ \rho^1$; the second crank will then have traveled 220° from

6*.

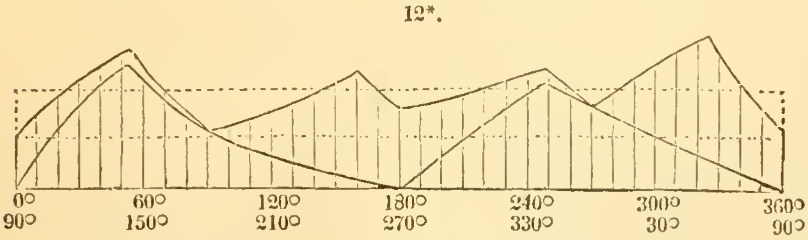



A A′, path of the two cranks.

9*.




12*.




the same point, and the combined tangential force will be represented by the line $\theta\ \rho^2$. The undulations of the upper line will therefore represent the inequalities of the working power in the crank-shaft throughout its whole revolution.

In laying down the forces in these diagrams, the following points have been assumed:

(*a*.) That as long as the steam-valve remains open, the pressure of the steam in the cylinder is uniform. This is not always the case in practice, but must generally be assumed in calculation.

(*b*.) That after the steam-valve is closed, the steam expands according to Mariotte's law, the pressure varying inversely as the volume. This is the usual assumption. The causes of variation from this law are treated of in works on the steam-engine, but cannot be comprised in an investigation of the present nature.

(*c*.) That no power is lost by friction in the transmission of the force through the machine.

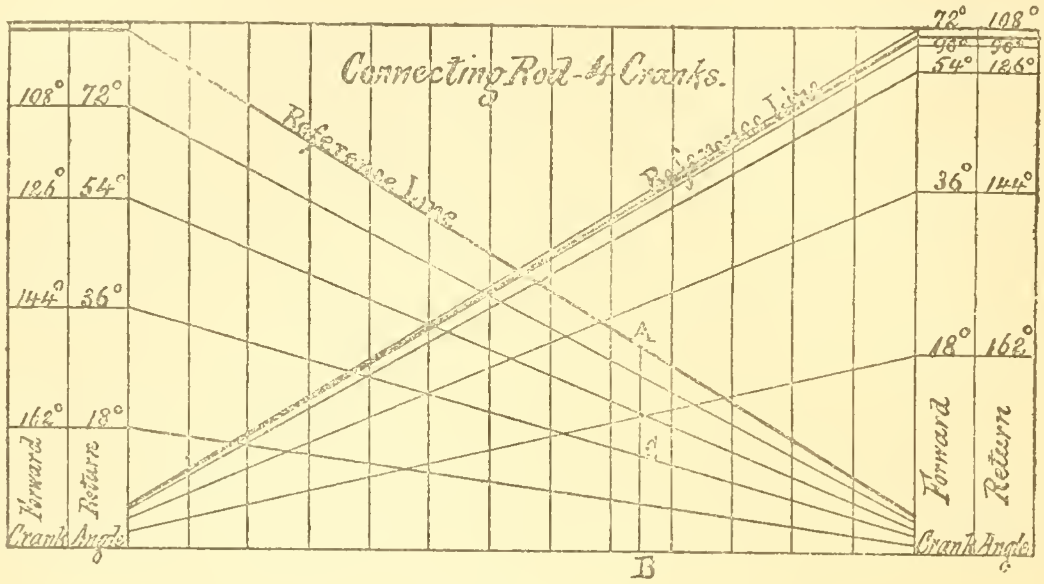
(*d*.) The influence of the clearance space on the volume of the steam, in expanding, has been neglected. This is but of small moment, and its introduction would have interfered materially with the simplicity and clearness of the diagrams.

(*e.*) The moving parts are supposed to have no weight or mass, the forces being considered in a statical point of view only.

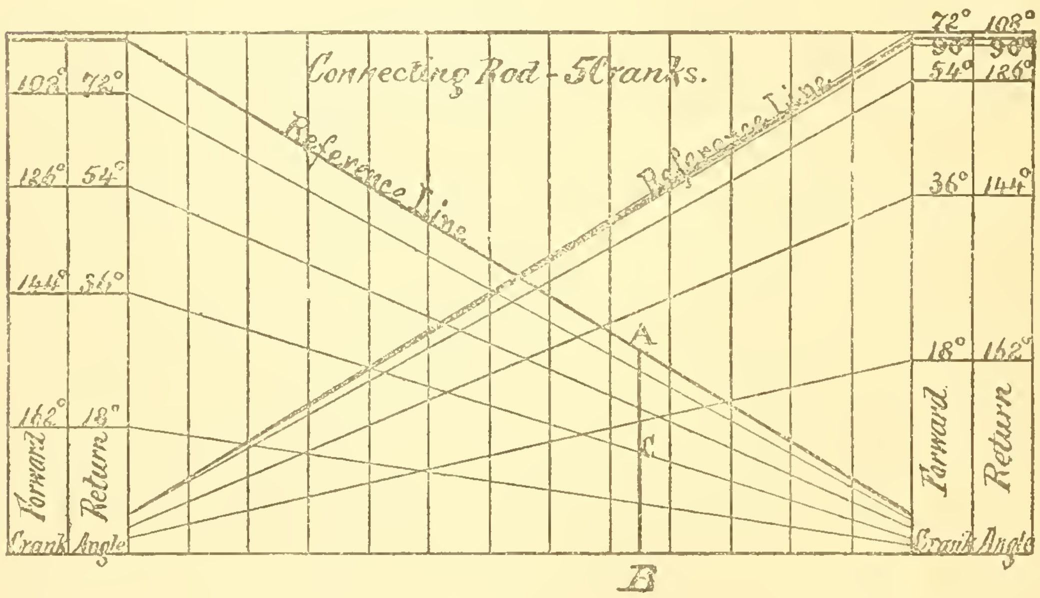
The curves have been formed by finding the length of ordinates at convenient distances apart, and tracing a curved line through the points thus obtained.

The methods of determining crank diagrams from the conditions of actual practice are fully de-

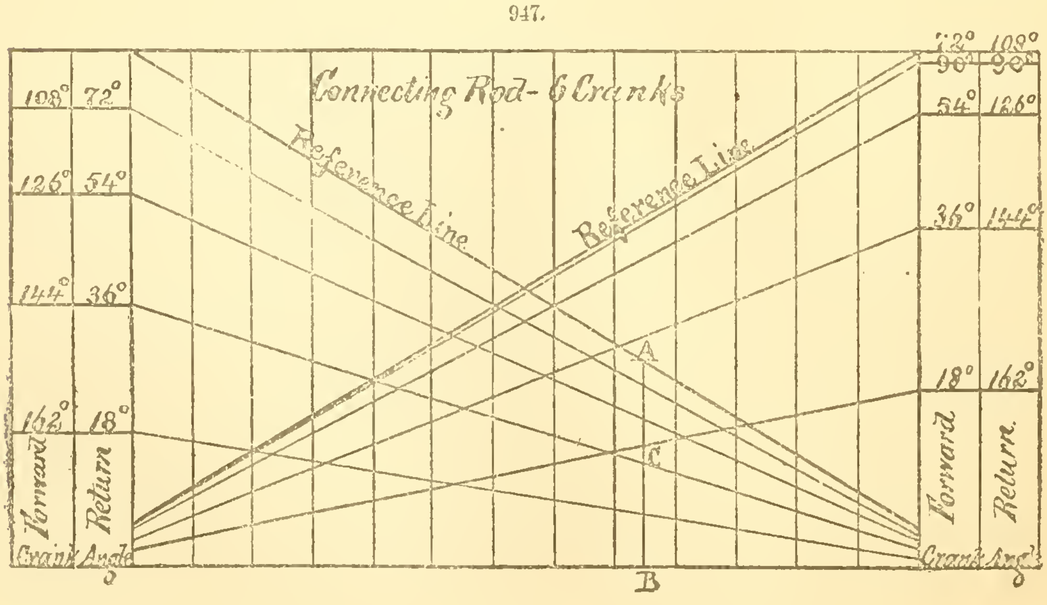
945.




946.

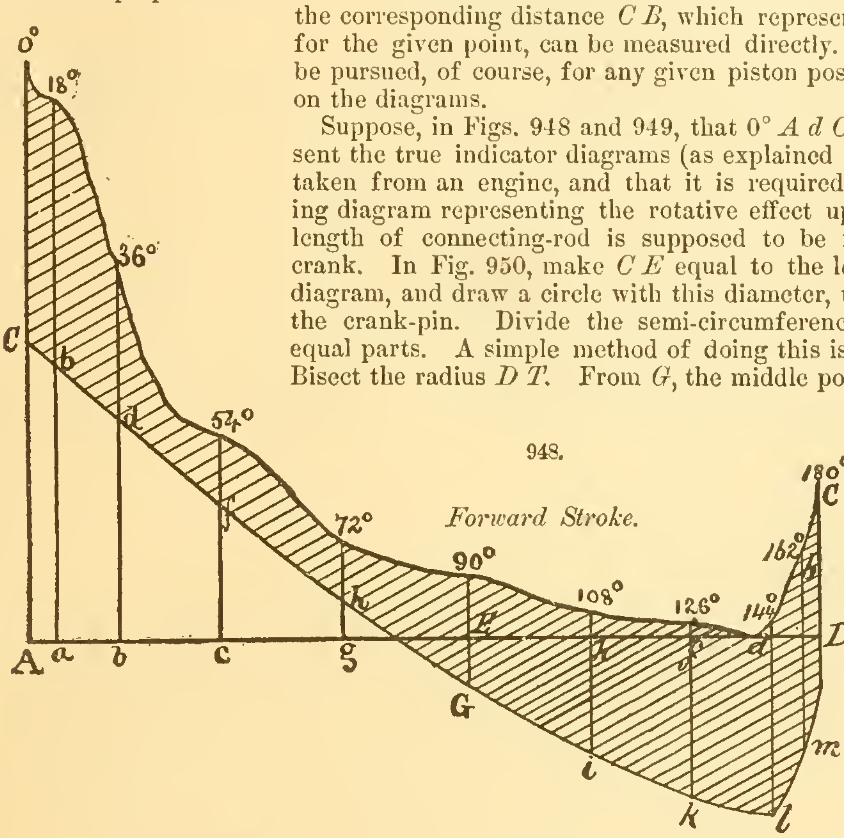



947.

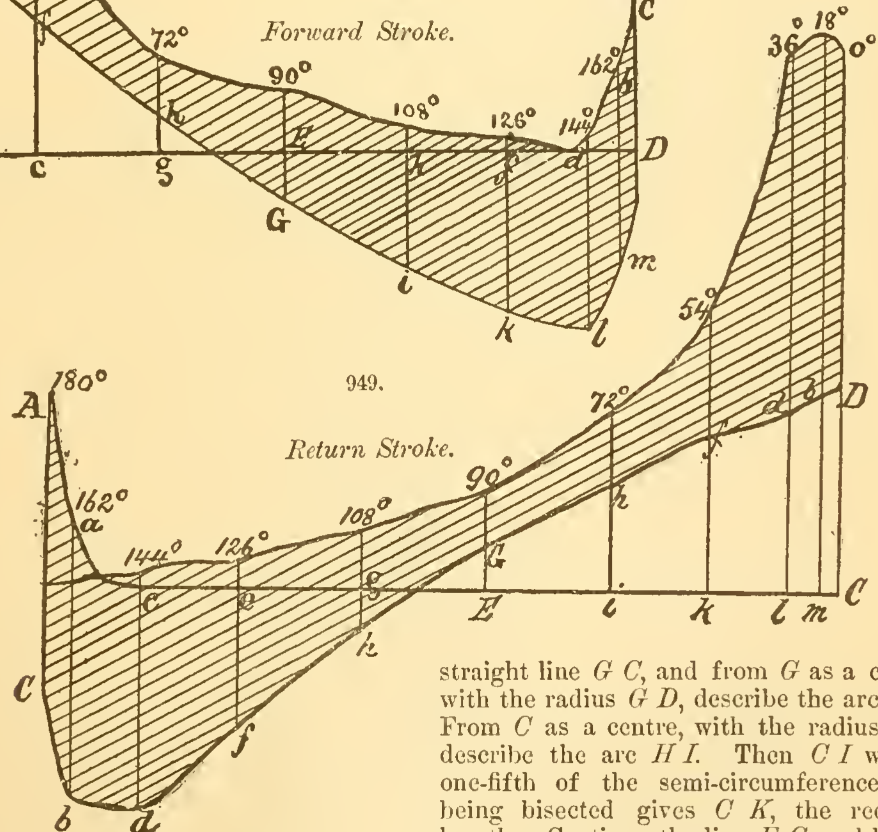


scribed and illustrated in Porter's work on the "Steam-Engine Indicator," and Rigg's "Practical Treatise on the Steam-Engine." The graphical determination of the correction for acceleration and retardation of the reciprocating parts, described below, is from the last-named work. Figs. 945, 946, and 947 give the rotative effect for connecting-rods 4, 5, and 6 times the length of crank respectively, at every twentieth of the revolution of the crank, for any pressure on the piston. They are carefully laid out from the same constructions as were made in determining Figs. 942, 943, and 944, and will be found useful in practice. The manner of constructing and using them needs but little explanation. Suppose, in either figure, that the pressure on the piston when it is in a position on the forward stroke corresponding to a crank-angle of 144°, or on the return stroke corresponding to a crank-angle of 36°, is equal to the line $A\ B$. It is only necessary to set a pair of dividers to this distance, and then move one point along the base line until the other point incloses the given distance in a perpendicular direction between the base and the line marked "Reference Line," when the corresponding distance $C\ B$, which represents the rotative pressure for the given point, can be measured directly. The same method is to be pursued, of course, for any given piston position which can be found on the diagrams.

Suppose, in Figs. 948 and 949, that 0° $A\ d\ C\ D$ and 0° $C\ c\ a\ A$ represent the true indicator diagrams (as explained in the article INDICATOR) taken from an engine, and that it is required to find the corresponding diagram representing the rotative effect upon the crank-pin. The length of connecting-rod is supposed to be five times the length of crank. In Fig. 950, make $C\ E$ equal to the length of either indicator diagram, and draw a circle with this diameter, to represent the path of the crank-pin. Divide the semi-circumference of this circle into 10 equal parts. A simple method of doing this is illustrated in the figure. Bisect the radius $D\ T$. From $G$, the middle point, as a centre, draw the




948.




949.

straight line $G\ C$, and from $G$ as a centre, with the radius $G\ D$, describe the arc $D\ H$. From $C$ as a centre, with the radius $C\ H$, describe the arc $H\ I$. Then $C\ I$ will be one-fifth of the semi-circumference, and being bisected gives $C\ K$, the required length. Continue the line $E\ C$, and lay off the length of the diagram, to represent the stroke of the piston, so that its outer extremity is five times $D\ C$ from the point $C$. Then find the points of stroke corresponding to the several crank positions laid off in the circle, observing that the last position on the forward stroke is the first position on the return stroke, the next to the last on the forward is the second on the return, and so on. (The references to forward and return stroke are for direct-acting engines, the forward stroke being that in which the piston moves from the end of the cylinder that is farthest away from the crank. In back-acting engines, where the cylinder is between the guides and crank, the forward stroke corresponds to the return stroke in direct-acting engines.) The points so determined on the line representing the stroke of the piston are then to be transferred to the indicator diagrams, Figs. 948, 949, and perpendiculars erected, as shown. It will be seen from these figures that while the crank-pin is passing over successive equal intervals, the corresponding spaces through which the piston moves are unequal. Now, as the crank is revolving at a practically uniform speed, it is evident that the motion of the piston is being accelerated during one portion of the stroke, and

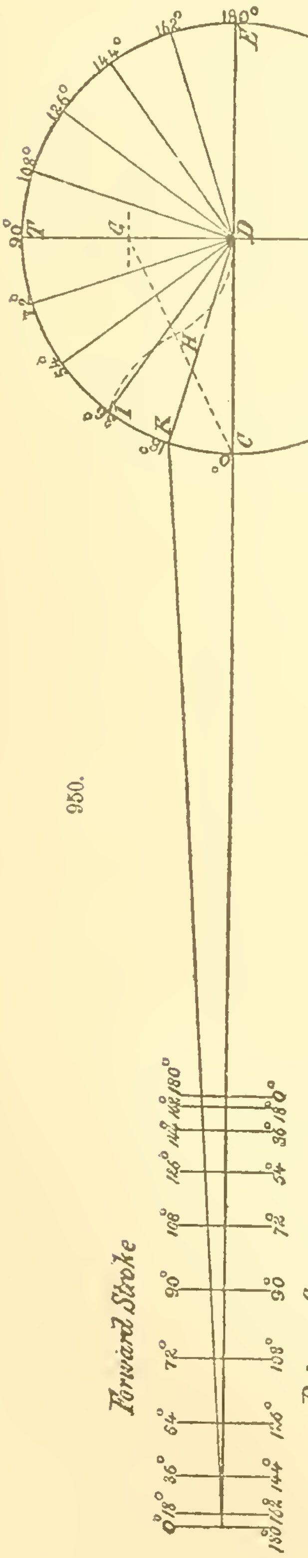
retarded during the other. Force is required to produce this acceleration, and is given out during the retardation; so that the indicator diagrams, Figs. 948, 949, do not represent the true distribution of pressure on the piston. The force absorbed by the reciprocating parts is greatest when the engine is on the centre, and at this time its value, in pounds per square inch for a connecting-rod of infinite length, is

$$\frac{0.000341 \times \left(\begin{array}{c}\text{revolutions of en-}\\\text{gine per minute}\end{array}\right)^2 \times \left(\begin{array}{c}\text{weight of reciprocating}\\\text{parts, in pounds,}\end{array}\right) \times \left(\begin{array}{c}\text{radius of crank,}\\\text{in feet,}\end{array}\right)}{\text{area of piston in square inches.}}$$

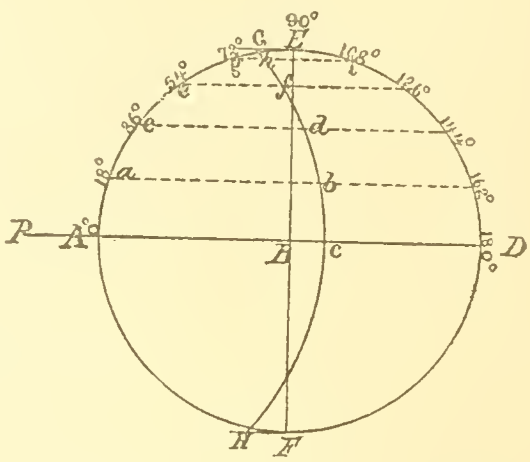
If, for example, an engine has a cylinder 20 inches in diameter and 4 feet stroke, and makes 60 revolutions per minute, the weight of the reciprocating parts being 500 lbs., the foregoing expression gives for the accelerating pressure, in pounds per square inch,

$$\frac{0.000341 \times 3600 \times 500 \times 2}{314.16} = 3.9.$$

Having determined the accelerating pressure at the commencement of stroke for a connecting-rod of infinite length, in the case under consideration, make $A\ B$, Fig. 951, equal to this pressure on the




950.



951.

scale of the indicator diagrams, Figs. 948, 949, and with $A\ B$ as a radius describe the circle $A\ E\ D$. As the connecting-rod in this instance is five times the length of the crank, make $B\ c$ equal to one-fifth of $A\ B$, and draw the diameter $T\ E$ at right angles to $A\ D$. At the extremities of this diameter draw lines parallel to $A\ D$, and lay off on these lines distances $T\ H$, $E\ C$, each equal to $B\ c$. Find $P$, the centre of a circle passing through the points $H$, $c$, and $C$, and draw the arc $H\ c\ C$, with $P\ c$ as a radius. Divide the semi-circumference $A\ E\ D$ into 10 equal parts, and through the points of division draw lines parallel to $A\ D$. Then $A\ c$, $a\ b$, $c\ d$, $e\ f$, etc., represent the pressures absorbed in accelerating the reciprocating parts, and $E\ C$, 108° $k$, 126° $f$, etc., represent the pressures given out during retardation for the forward stroke, and exactly the opposite for the return stroke. These pressures are then to be transferred to the diagrams, Figs. 948, 949, and added or subtracted, according as they represent pressures absorbed or given out. In this manner the outlines of new diagrams, which show the true distribution of pressure on the piston, and which are distinguished by being shaded, are produced. To transfer these pressures to the crank diagram, make $A\ G$, Fig. 952, equal to the distance traveled by the piston in one revolution, on the same scale as the previous diagrams. A method of drawing a circumference corresponding to a given diameter that is exceedingly accurate is shown in the figure. $A\ B$ is the given diameter. At the extremity $A$ erect the perpendicular $A\ F$; make $A\ C$ equal to the radius, and divide it into 5 equal parts. From $B$, the other extremity of the given diameter, lay off $B\ D$ equal to one-fifth of $A\ C$, and $D\ E$ equal to two-fifths of $A\ C$; draw the straight lines $C\ D$, $C\ E$, make $A\ F$ equal to $C\ D$, and draw $F\ G$ parallel to $C\ E$; then $A\ G$ will be the circumference of the circle whose radius is $A\ B$. Divide this circumference into 20 equal parts, which can be done as indicated by the dotted lines. From $A$ draw a straight line $A\ H$, and lay off from $A$ toward $H$ any distance 20 times. Connect the last point $H$ with $G$, and through the several points of division draw lines parallel to $H\ G$, which will divide $A\ G$

into 20 equal parts. Erect perpendiculars at the several points of division which correspond to the crank positions in Fig. 950. Find from the diagram Fig. 946 the rotative pressures corresponding to the pressures in the shaded diagrams, Figs. 948, 949, and lay them off on the corresponding perpendiculars in Fig. 952. A curve drawn through the points so determined, as indicated, will represent the effective pressure on the crank-pin during a revolution; and if the area included between this curve and the base line is measured, a line representing the mean pressure can be drawn parallel to the base line, including an area equal to that between the curve and the base line. This equivalent area is distinguished by shading in Fig. 952, and it will be seen that it is so drawn as to add an area equivalent to that cut off from the original crank diagram. The area of an irregular figure similar to that in Fig. 952 can be measured with great accuracy by an instrument called the planim-

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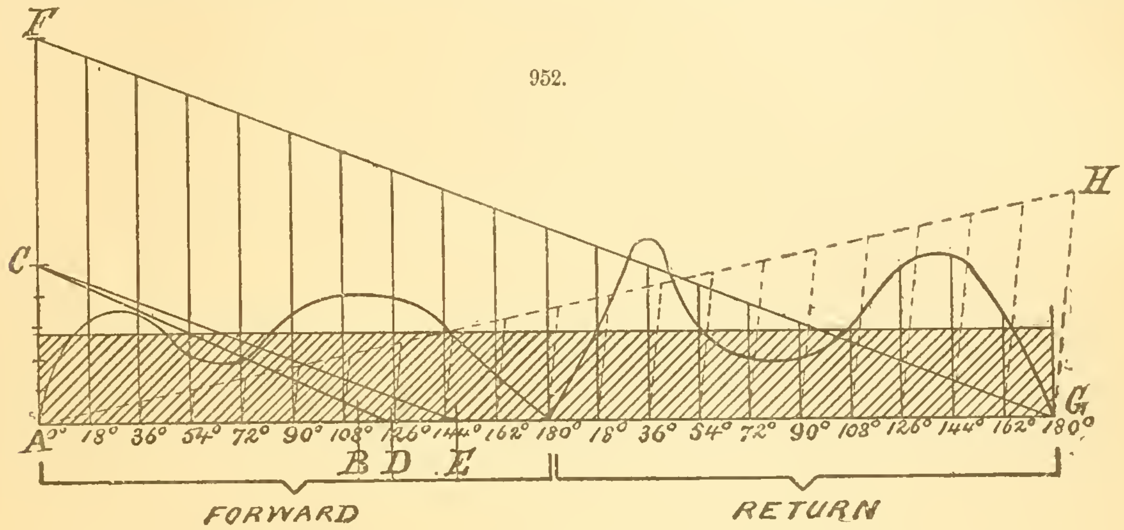


eter, which calculates mechanically the area of a figure whose boundaries are traversed by a pointer; or it can be computed by the aid of Simpson's rule, which is explained in most works on mensuration, among which may be mentioned Prof. Rankine's "Useful Rules and Tables."

The effect of the reciprocating parts on the distribution of pressure throughout the stroke of the piston was first pointed out by Charles T. Porter, and the Porter-Allen engine is designed to produce an even distribution by the application of this principle. It is easy to see that by varying the weight of the reciprocating parts, and the speed of the engine, almost any desired distribution of pressure may be effected.

See SLIDE-VALVE for a table showing piston and crank positions for connecting-rods of different lengths. The formulas by which they were computed are appended, as well as rules for the estimation of rotative effect, the latter being taken from H. Tresca's "Course in Applied Mechanics." If $c$ = ratio of length of connecting-rod to length of stroke, $r$ = fraction of stroke completed when crank angle = $C$, and $a$ = distance from centre of cross-head to centre of shaft:

For the forward stroke—

$$a = c + 0.5 - r$$

$$\cos. C = \frac{a^2 + 0.25 - c^2}{a}$$

$$a = \left[c^2 + 0.25 - c \times \cos.\ \left(180° - C - \text{arc sin.}\ \frac{\sin. C}{2c}\right)\right]^{\frac{1}{2}}$$

$$r = c + 0.5 - a$$

For the return stroke—

$$a = c - 0.5 + r$$

$$\cos. (180° - C) = \frac{a^2 + 0.25 - c^2}{a}$$

$$a = \left[c^2 + 0.25 - c \times \cos.\ \left(C - \text{arc sin.}\ \frac{\sin. C}{2c}\right)\right]^{\frac{1}{2}}$$

$$r = a + 0.5 - c$$

If $P$ = pressure on piston, $p$ = corresponding rotative pressure on crank-pin, $\alpha$ = crank angle, $l$ = length of connecting-rod, and $r$ = length of crank—

$$p = P \times \sin. \alpha \times \left[1 - \frac{r \times \cos. \alpha}{(l^2 - r^2 \times \sin.^2 \alpha)^{\frac{1}{2}}}\right]$$

R. H. B.

CRAPING MACHINE. See CLOTH-FINISHING MACHINERY.

CROWN GLASS. See GLASS-MAKING.

CRUCIBLES. Vessels used for the fusion of certain metals, for assaying, and generally for many other chemical purposes in which intense heat is employed. The principal requisites of a good crucible are, that it should be capable of enduring the strongest heat without becoming soft or losing much of its substance; that it should not crack on being exposed to sudden alternations of temperature; that it should withstand the corrosive effect of the substance fused in it; and lastly, that it should be sufficiently strong to support the weight of the molten metal when lifted from the furnace.

Crucibles which become tender at a high temperature are then liable to break or crumble when grasped with the tongs, and are very dangerous.

*Clay crucibles* are made of fire-clay, mixed with silica, burnt clay, or other infusible matter. In order to counteract the tendency clay has to shrinking at high temperatures, the other substances are mixed with it. The proportion of burnt to raw clay may be varied, but two-thirds raw clay to one-third burnt clay is a very common proportion. It is necessary that there should be a sufficient quantity of raw clay to produce the proper degree of plasticity for working. The unburnt fire-clay must be ground, as must also the burnt clay, the latter generally consisting of old crucibles or glass-pots, which have been exposed to high temperatures. The surfaces of these old pots must be cleaned from all extraneous matter, and their vitrified coating be chipped off. Clays which contain a maximum quantity of pure silica are best adapted for the most infusible crucibles, if in addition they are comparatively free from such injurious admixtures as lime or iron; and the infusible properties can be strengthened by additions of burnt clay, such as we have indicated, or of powdered coke and plumbago. The celebrated Berlin crucibles are made from 8 parts fire-clay, 4 parts black lead, 5 parts powdered coke, 3 parts old ground crucibles. Another mixture is 2 parts fire-clay, 1 part ground gas-coke. The materials should be as free from lime as possible, well kneaded together, and slowly dried in a kiln. When fire-clay is not easily obtainable, as a substitute for it steep common clay in hot hydrochloric acid, wash it well with hot water, and dry it.

The crucibles in most common use in Birmingham and its neighborhood, as well as in Sheffield, England, are made of a fire-clay found near Stourbridge, which is generally mixed with some other substance, such as powdered coke, in order to lessen its tendency to contract when strongly heated. The following are about the average proportions: 4 parts fire-clay, 2 burnt clay cement, 1 ground coke, 1 ground pipe-clay. These Stourbridge-clay crucibles, or casting-pots, are only carefully dried, but not burned until required for use, when they are put into the melting-furnace first with the mouth downward, and when red-hot are taken out, and put in again with the mouth upward. The melting-pots or crucibles employed by Mushet in the manufacture of cast-steel, or homogeneous metal, were made by mixing kaolin or china clay with black or gray fire-clay from the coal measures, and pulverized old pots, the clays being passed through riddles having 64 to 100 meshes to the square inch. The proportions used by Mushet are 5 parts by measure fire-clay, 5 parts kaolin, 1 part old pot, and 1½ part coke-dust; the ingredients being well mixed, and then kneaded, tempered, and moulded in the usual way.

When it is necessary to protect a crucible from the corrosive action of the material to be melted in it, it can be lined with charcoal powder or black lead. In a small crucible, the powder may be made into a paste with a little gum-water or molasses, and rammed into the crucible, the central cavity being afterward shaped by a small rammer of the desired form. For larger crucibles, a mixture of anthracite powder, powder of gas-retort carbon, or gas-tar may be employed. To test crucibles as to power to resist corrosion, protoxide of lead, or a mixture of protoxide of lead and dioxide of copper, is melted in the crucible. If a clay crucible is not permeated or corroded by this mixture to a sensible extent after a short time, it may be considered capable of resisting all ordinary corrosions in practice. As a rule, clay crucibles resist permeation and corrosion in the proportion of the fineness and regularity of grain, but their tendency to crack is increased in the same ratio.

Cornish crucibles are principally used for assaying copper; they are made of a clay found in some parts of Cornwall, and the smaller sizes are capable of resisting sudden alternations of temperature, a quality which is probably due to the large proportion of silica mixed with the clay, but they are rapidly corroded by melted oxide of lead. Hessian crucibles were formerly employed to a much greater extent in metallurgical operations than they are at present. They are made principally from a clay found at Gross-Almerode, and in their composition resemble very closely the Cornish crucibles. The form is triangular, and they are generally packed in nests of six, the smaller sizes fitting into the larger. These crucibles are tolerably lasting at moderate temperatures, but are apt to fuse when exposed to very great heat. Several kinds of French crucibles are manufactured, some of which are of very excellent quality, especially those of Beaufay, called the *creusets de Paris*, and those of Deyeux, termed *creusets de Saveignies*. Both kinds, however, contain a large percentage of oxide of iron, which renders them objectionable for some purposes. London crucibles are of a reddish-brown tint, very close-grained, and capable of resisting the corrosive action of oxide of lead, but liable to crack when suddenly heated. They are made of various sizes, from 2¼ inches up to 8½ inches in height. For special metallurgical or chemical purposes, crucibles are sometimes composed of platinum, lime, bone-dust, magnesia, pure carbon, and other materials.

Crucibles are made of various forms and sizes, according to the kind of work for which they are intended; those used for assaying are scarcely larger than a lady's thimble, while others made for zincing shot will hold as much as 800 lbs. of molten zinc. Some are nearly cylindrical, others triangular, and others skittle-shaped. *A*, Fig. 953, shows the pot and cover employed in melting steel, while *B* is a common form of crucible for brass and the like. Small crucibles are generally kiln-burnt before being used; larger crucibles are usually dried gradually in hot stoves. Where the crucibles or pots, as they are familiarly termed, are made of fire-clay and upon the works, the pot flask, or mould, and plug are commonly of the forms *C* and *D*. The pot mould is of cast-iron, with two ears cast upon it to lift it by. Its inside is the shape of the outside of the pots; it is turned smooth, and is open at the bottom as well as the top. There is a loose bottom made to fit, but not so small as to pass through; this has a hole in the centre, three-quarters of an inch in diameter. When in use it stands upon a low post firmly fixed in the ground, which also has a hole 5 or 6 inches deep in its centre. The plug which forms the inside of the pot is of lignum vitæ; it has an iron centre which projects through it about 5 inches, corresponding in size with the hole at the bottom of the mould.

The clay for a steel-pot weighs about 24 lbs.; it is moulded upon a strong bench into a short cylin-

der, and, the inside of the mould having been well oiled, the clay is dropped into it, and the plug, also oiled, forced into the clay, while the projection finds the hole in the loose bottom in the centre of the mould, which guides the plug. The plug is driven down 2 or 3 inches by the blows of a heavy mallet on the top of the iron head; it is then taken out to be oiled again by putting a piece of round iron through the hole in the iron head to lift by, giving it at the same time a screwing motion. It is

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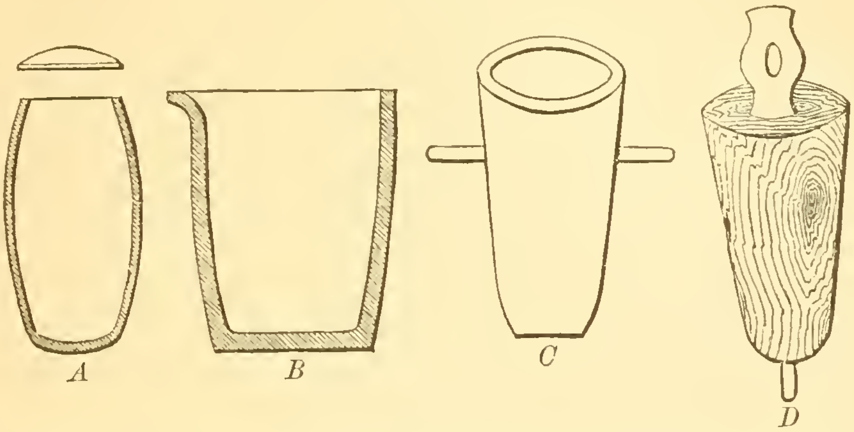


then driven by the mallet, while the clay, rising up between the plug and the mould, reaches the top. The clay is cut even with the top of the mould by passing the knife round between it and the flask or mould several times, holding it inclined toward its centre. The mould is now taken and set with its loose bottom upon a small post fixed in the floor, and gently allowed to rest upon it. This pushes up the bottom with the pot upon it; and the hole being filled with a bit of clay, the pot is finished. When the pots are sufficiently hard to bear handling, they are placed to dry upon rows of shelves against the flues in the furnace, where they remain from 10 to 14 days. Before use they are annealed by being placed from 17 to 20 hours in a special annealing furnace; and they are taken directly from this and placed for use hot into the melting-furnace.

Crucibles are frequently made on an ordinary potter's wheel, and special machines are also employed for the same purpose. One of these, T. V. Morgan's machine for making either large or small crucibles, is illustrated by Fig. 954. The peculiar mechanical arrangement consists in fitting the former, or forming tool employed in the apparatus, so that, in addition to being capable of an up-and-down movement, the former is free to be moved and adjusted horizontally as the crucible is being moulded, and according to the required size or thickness of the crucible. When a crucible is to be made, the frame is pulled down to cause the former to enter the plastic material, which is placed in a mould, on a revolving lathe or jigger, as usual; and when the former reaches the bottom of its course, a catch on one of the uprights secures the frame in position. The threaded rod is then turned, to cause the former to move horizontally and spread the plastic material against the side of the mould. Finally, the back end of a lever carried on the top of the frame, and free to move backward by means of a slot or otherwise, is inserted into a hole formed for the purpose, and its forward end is pressed down by hand, so that the lever bears forcibly upon the frame, and prevents all vibration or movement of the former. When the crucible is finished, the handle is turned to bring the former to the centre of the crucible, the lever is moved forward out of its hole, the catch released, and the frame raised up by a balance-weight. The operation is then repeated for the next crucible, and so on. Fig. 954 is a section of Morgan's apparatus. *a* is the former, or forming tool; it is fitted to a block *b*, which is, as before stated, free to be moved horizontally in a frame *c* by means of a screw *d*, taking into a corresponding thread in a nut in the block *b*; the ends of the screw *d* work in fixed nuts on the frame *c*, and the right-hand end is provided with a handle *g*, which is turned according as the former *a* and block *b* are required to be moved. The frame *c* is free to move up and down in slots formed in two uprights, and its weight is counterbalanced by weights *k k*,

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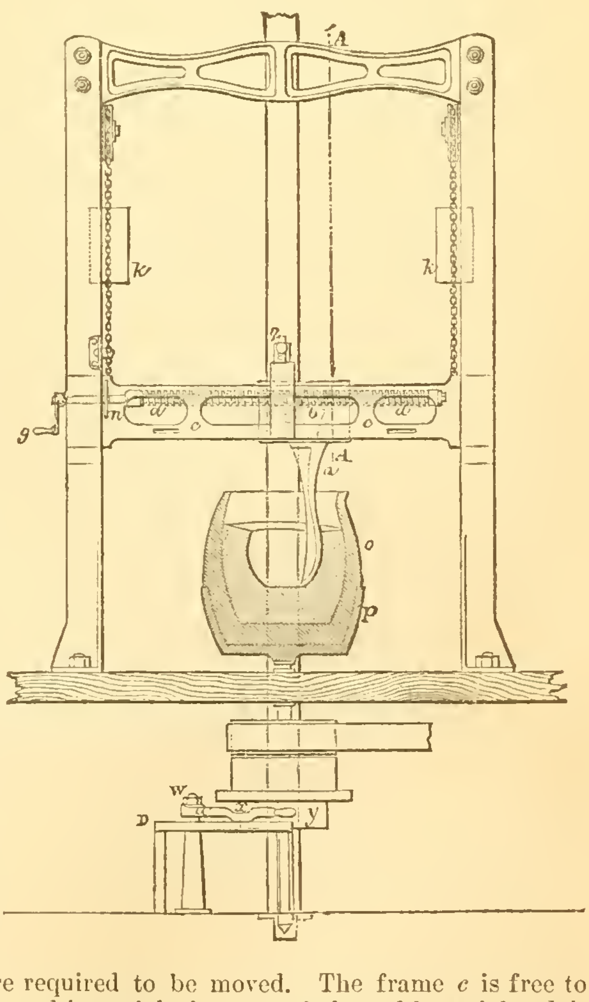

on the end of chains or cords passed over pulleys and connected to the frame. *n* is a catch on the upright to secure the frame *c* in position when the former *a* reaches its lowest position. *o* is the mould into which the plastic material is fed; this mould is carried on an ordinary lathe or jigger *p*, to which rotary motion is imparted as usual. When the frame *c* is caught by the catch *n*, and the mould is caused to rotate, the screw *d* is turned by its handle *g*, so as to cause the former *a* to move horizontally, and spread the plastic material against the side of the mould; and when it has been moved to the required distance, which is regulated by a scale on the frame, the back end of a lever *q*, carried on the top of the frame and free to move backward by means of a slot, is inserted into a hole formed in an upright, and its forward end is then pressed down by the attendant so that this lever bears forcibly upon the frame *c* and prevents vibration or movement of the former. When the crucible is finished, the handle *g* is turned to bring the former *a* to the centre of the crucible, the lever *q* is moved forward out of its hole, the catch *n* is released, the frame is raised up, and the mould is removed in the ordinary manner; all being then ready for the next operation. *u* is a horizontal bar, under the platform and hinged at *w*, while its front end extends to the front of the apparatus. *x* is a block on the bar *u*, and *y* is a collar on the lathe-shaft. When it is required to stop the revolution of the lathe, the attendant moves the bar *u* on its hinge *w*, so as to bring the block *x* against the collar *y*. *z* is a horizontal bar or guide for the bar *u*. (The foregoing is abridged from Spretson's "Casting and Founding.")

For *graphite crucibles* the foliated form of graphite (see GRAPHITE) is employed, and it undergoes grinding as a preliminary process. It should not be ground so fine as to lose the appearance of scales. With the plumbago thus prepared is mingled a small proportion of kaolin or china clay, varying according to the use for which the crucible to be made is intended. To every 10 parts of graphite is also added 7 parts of a gray clay which is imported from Klingenberg in Bavaria, besides a little ground charcoal, the latter to secure porosity. These ingredients are mixed dry; water is afterward added, and the compound passes to a huge cast-iron cylinder capable of holding about 3 tons. Here thorough stirring is done by means of arms arranged radially on a central vertical rotating shaft. Each arm, besides having four vertical beveled blades, is made flat above and beveled below, so that the mass undergoes a kneading which secures its rapid and homogeneous mixing. The material emerges of the consistence of thick dough, and is at once moulded into crucibles. This is done either by hand or machinery, special forms being made in the former way.

The machine process is exactly the same as that in common use by potters for moulding plates, teacups, etc. A plaster mould is prepared, which is placed on the rotating wheel. Into this the ball of graphite dough is placed; and as the mould rotates, a former is brought down into it from above, which carries the material out against the sides and forms the inner cavity, according to gauges previously adjusted. The mould is then taken from the lathe; and after the crucible has become dry enough, the latter is turned out, placed upside down on the wheel, and its exterior smoothed by hand.

The baking process, which next ensues, does not differ from that followed by potters. Each crucible is inclosed in a large fire-clay vessel, known as a "sagger," and a number of these are heaped up in the kiln. A "number" in crucible-making means 2 lbs. of material. When the baking is finished the crucibles emerge hard, and varying in color from grayish white to blue-gray. The difference in hue is no criterion of quality, and is simply due to cracks or other imperfections in the saggers.

In point of size, plumbago crucibles hold from 2 ounces up to 600 lbs. Their average lifetime in brass-making is from 35 to 45 heats. Clay crucibles can be used but once. For melting steel they will run from 4 to 6 times, and longer if coated with a mixture of fire-clay, plumbago, charcoal (or better, gas-carbon), and silica (pure fine quartz sand). Care should be taken to remove slag from the surface after each melting. Old steel-pots are freed from slag, ground up, and remanufactured into crucibles. The same "metal" used for crucible-making is also formed into plugs or valves in the ladles used for conveying molten steel, made by the Bessemer process, to the moulds. Plumbago crucibles may be generally employed, except in cases where a flux is used, as the flux would eat the clay from the plumbago. In using them, they should be kept in a dry place, the least dampness being fatal. It is well, for the first time of using, to put the crucible in the furnace at the time of lighting the fire, so that it heats up gradually with its surroundings. The pot should be placed in the fire and not on it, and the fire should surround it to the very top.

CRUSHER. See BREAKER OR CRUSHER.

CULTIVATOR. See AGRICULTURAL MACHINERY.

CUPEL. See ASSAYING.

CUPOLA FURNACE. See FURNACE, CUPOLA.

CURD-KNIVES. See DAIRY APPARATUS.

CUT-OFF. See ENGINES, STEAM, STATIONARY RECIPROCATING.

DAIRY APPARATUS. The following list comprises the apparatus and supplies necessary for the fitting up of a dairy factory for the manufacture of cheese and butter, receiving the milk of about 450 cows:

1 steam-boiler, 4 horse-power, and fittings.
2 600-gallon steam-vats, complete.
16 cheese-press screws, 20 inches long, $1\frac{3}{4}$ inch diameter.
1 milk-conductor (can to vats).
1 curd-knife, 13 blades, 20 inches long.
1 curd-knife, horizontal blades, $6 \times 20$ inches.
1 set hoisting-crane castings.
1 curd-scoop.
1 set stencil-plates, for dating cheeses.
1 set stencil-plates, paste, sponge, and brush.
1 wrench, No. 3.
1 large slate.
2 thermometers.

1 scrubber mop.
1 cheese-tryer.
1 steam-engine, 4 horse-power.
16 galvanized iron cheese-hoops, with follower 15 inches diameter.
1 standard scales, 600 lbs.
1 standard scales, 240 lbs.
1 weight-can, 60 gallons, large faucet.
1 curd-pail.
1 best-pail.
1 factory stencil-plate.
2 rennet jars, 15 gallons.
1 factory account-book.
1 set of milk-testing instruments.
1 curd-mill.
1 set casters for curd-sink.
1 siphon, with valve and faucet.
1 siphon strainer.
Patent milk-pans.
Factory churns.
Butter-bowls.
Butter-moulds.
Butter-workers.
Cheese-bandage.
Linen strainer.
Annotto.
Steam-pipes, joints, valves, etc.
Belting.
Cooler-pails.
Pans.
Press and cap cloths.
Rennets.
Dairy salt (F. F.)

Milk is delivered at the dairy in cans, of which there are several varieties in use. They are made with only one seam, and the bottoms are of wrought-iron, and tinned. Their capacity is from 15 to 50 gallons.

Ventilated milk-cans are used in order to allow the "animal odor" of the milk to escape, so that the milk will not become tainted. Undoubtedly, if milk from cows in abnormal conditions is to be transported, ventilation will be of great advantage; but if it is positively known that the milk is from cows in perfect health, ventilation is entirely unnecessary, as has been practically demonstrated by Hardin's method of making butter, where every favorable condition is presented to injure the milk if the "animal odor" possessed any such injurious properties. Still, for fear that the milk from one cow in an abnormal condition might be mixed with the rest of the milk, ventilated cans

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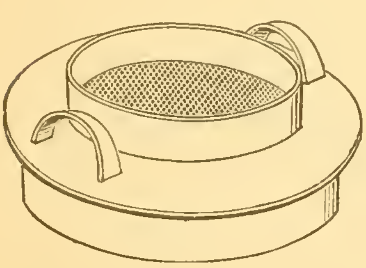

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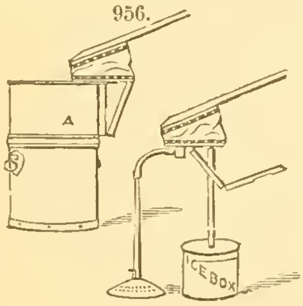

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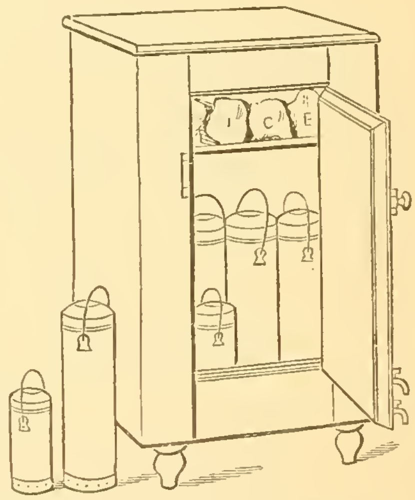

are of great value, and their more general use is desirable. The simplest ventilator is one invented by L. B. Arnold, and represented in Fig. 955. It is made by cutting a circular orifice in the cover of a can, and soldering over the aperture a piece of coarsely perforated tin, or of wire cloth, giving the latter a moderate depression in the middle. Around the outside of the wire cloth is soldered a flange of tin, 2 inches high, to prevent loss of milk.

Milk is sometimes aërated before it is put into the cans for transportation. If such be the case, the atmosphere must be pure and sweet, and free from any injurious offensive odor. The *deodorizing strainer and cooler*, invented by Bussey, is simply a strainer-pail, raised about 2 feet above the can, and arranged so that the milk falls in a spray into the can. Another method of aëration was invented by Jones & Faulkner, and consists in forcing air into the milk. Fig. 956 shows the manner in which this is accomplished.

*Vessels for Setting Milk.*—The old method of setting milk in small tin pans is rapidly being limited to the farm-house. The pans hold from 8 to 10 quarts, are light, and are easily handled. They cool the milk readily without the use of water, and are easily cleansed; but they are not suitable for large dairies. Another method of setting milk is in large pails, which are usually made of sheets of tin 24 × 20 inches, and are from 19 to 22 inches high, and nearly 8 inches in diameter. These pails are filled with milk within 4 or 5 inches of the top, and are then placed in "pools" to allow the cream to rise. Care must be taken that the surface of the milk in the pails is not above that of the water in the pools.

An attempt has been made by Mr. Hardin to do away with the "pools" for setting milk, by the introduction of a sort of refrigerator. His method is shown in Fig. 957. As it is the nature of heated air to ascend, the ice-shelf is placed in the top of the box, to secure uniform temperature. A space of 1 inch is left open on each side of the shelf, to allow the air to pass around the ice. The drippings from the ice are utilized to the extent of 4 inches in the bottom of the box. The cans are made with a perforated rim on the bottom, to allow the water to pass under them. The covers of the cans fit outside, so as to shed the water, and prevent any of the drippings from the ice getting into the milk.

A milk-can designed to take the place of the water-pools and deep pails mentioned above is represented in Fig. 958. A complete set consists of four pans, with wooden vats containing them, and the framework on which they stand, together with the supply water-pipe, skimmer, etc.; also all

spouts necessary to operate them. The water is first passed through the centre of the milk and near the surface, after which it surrounds the pan completely, always standing higher than the milk, to prevent drying of the cream. The size of the milk-pans varies; some hold 8 gallons, others 90 gallons of milk at a time.

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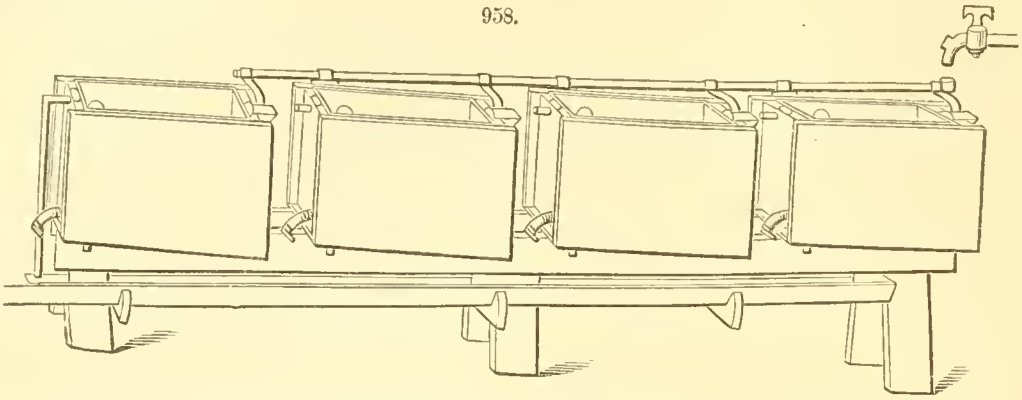

Another method of setting milk for cream is by means of shallow pans, of which there are a great many varieties in use.

The Orange County milk-pan is shown in Fig. 959, and a section of the pan in Fig. 960, from

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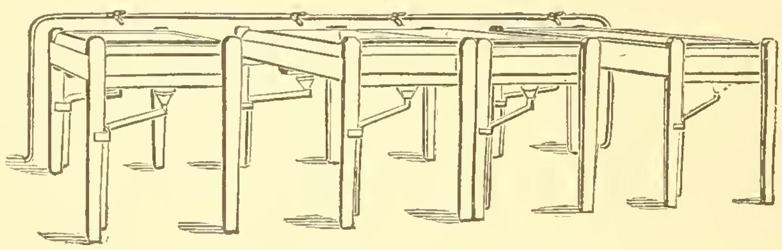

which it will be seen that *A* represents the milk-pan, which is made of tin. The water-vat *B* is made from galvanized sheet-iron. The patent water-regulator *E* is a hollow tube that can be raised or lowered at pleasure. The situation of the top of this regulator determines the depth of

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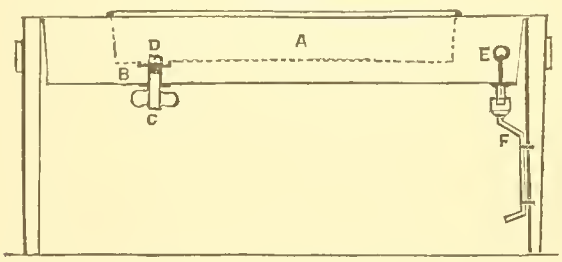


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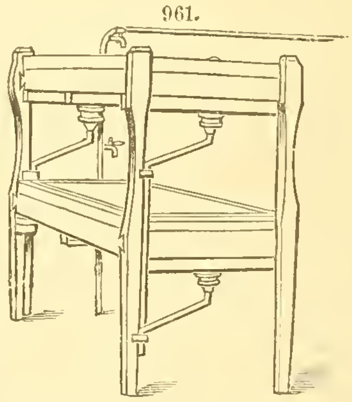
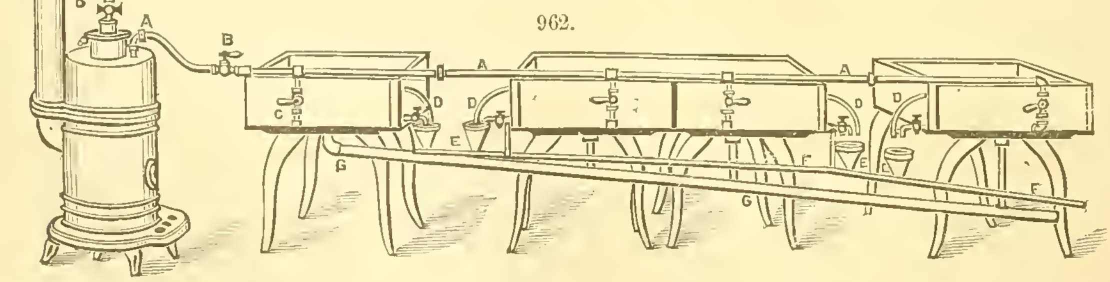


the water in the vat. The water rises in the vat around the milk-pans to the top of the regulator, then passes down through it into the pipe *F*, and is conducted off. With this device the temperature is perfectly controlled. The bottom of the water-vat is supported by a movable board-bottom in the rack, and between this board-bottom and the metal water-vat is put a waterproof lining, which is a non-conductor of heat, and which prevents the atmosphere of the room from coming in contact with the bottom of the vat, thereby leaving all the cooling properties of the water to be used upon and to control the temperature of the milk. At each end of the pan in the vat there is a space for ice to be stored, and, as it melts, the water passes off down through the regulator pipe. The Orange County milk-pan

962.

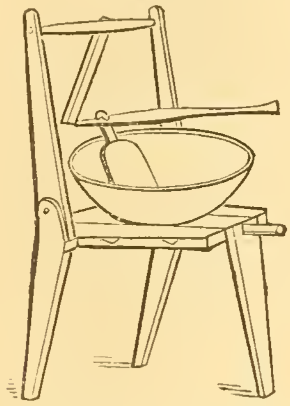



is made in double racks also, as shown in Fig. 961. When so arranged, the upper pan is reached by means of a movable platform, which is kept under the rack, and, when wanted, is drawn out. By use of the double rack a set for 30 cows can be used in a room 8 × 10 feet.

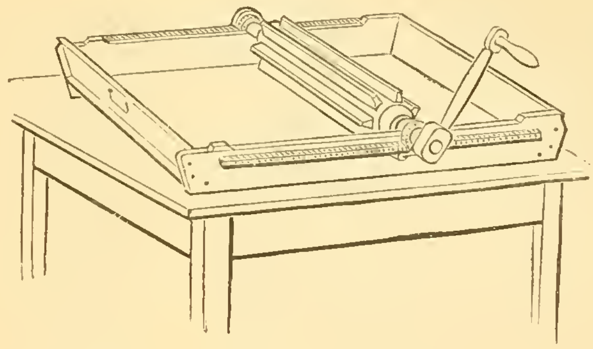
The iron-clad pan is represented in Fig. 962. The illustration shows the pan fitted with steam

apparatus, so that the temperature of the milk may be held at pleasure. If the "scalding process" for raising cream be adopted, the attachments to this pan render it very applicable for such object; or if the ordinary process be employed, the cold-water pipes connected with the pan adapt it to that system. In Fig. 962, pipes $A$ are for the water-supply, $F$ the waste-water pipe, $G$ the sour-milk

963.



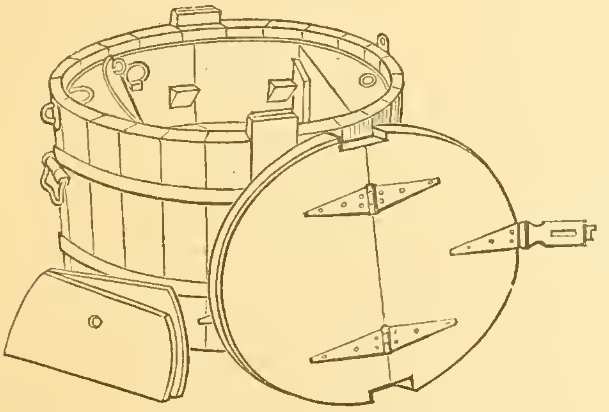
964.



pipe, and opposite $C$ on the other side is placed a thermometer for regulating the hot and cold water. (For conversion of milk into butter, see CHURNS.)

*Butter-Workers.*—The common wooden bowl and ladle are still in use in small dairies for working butter, and are undoubtedly the best for the manufacture of butter on a small scale. For an extensive manufacture, though, other devices become more economical.

965.

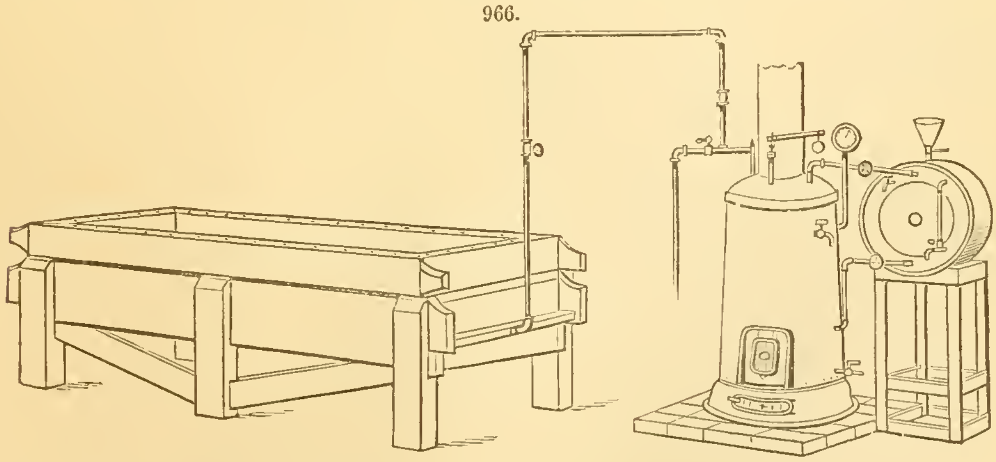


An improved butter-worker is shown in Fig. 963. It consists of an ordinary butter-bowl attached to a stand, on which it is free to revolve. A ladle is attached to a lever over the bowl in such a manner that it can be worked up and down, from one side of the bowl to the other, and, in fact, in all directions. "Reid's butter-worker" is shown in Fig. 964. It consists of a tray and a roller with paddles, which is turned by a crank, and traverses from end to end of the tray. The roller can be readily removed when desired, which leaves a table to weigh and print off of.

*Butter Packages.*—Butter is packed in firkins, in half firkins, in kegs, and in pails. The best firkins and kegs are made of white oak, heavily hooped, and the sides neatly turned.

An improved form of butter-tub and cooler is shown in Fig. 965. It is made of white cedar, and bound with galvanized iron or brass hoops. Within the tub is fitted a tin cooler, having a movable chamber for ice at each end. On the tin is constructed a series of ledges, on which rest the shelves for supporting the butter (print butter); it is used without shelves for roll butter.

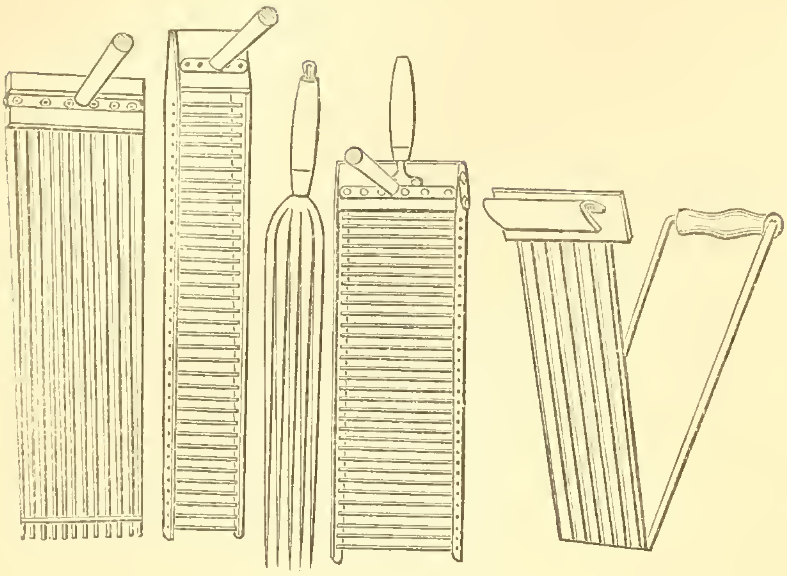
966.



CHEESE-MAKING.—*Cheese-Vats.*—Quite a variety of cheese-vats are in use, but as they are built mostly alike, a description of the most prominent ones will be all that is necessary. They all consist of a large inner vat of tin, generally capable of holding from 400 to 650 gallons of milk, suspended in a wooden envelope, leaving a space between the two for steam or water, or to heat or cool the same. The tin vat is arranged so that it may be removed at pleasure.

Fig. 966 represents a cheese-vat and engine complete. The vat has a capacity of 600 gallons. The wooden envelope, or vat, is generally made of well-seasoned pine. The tin for the inner vat is

967.

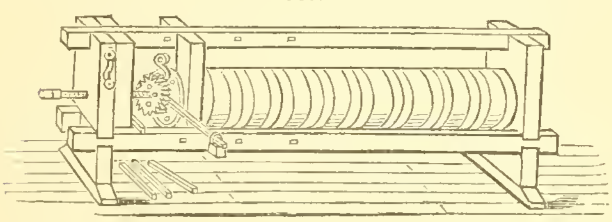


imported expressly for this purpose. They vary in size from 12 to 16 feet long, and from 3 to $3\frac{1}{2}$ feet wide, and 19 inches deep. In small creameries and farm-dairies, cheese-vats called "self-heaters" are often used.

There are several methods for warming milk and heating curds; but Prof. Arnold states, after trying them all, that "throwing steam directly under the milk or whey to be heated is the simplest and cheapest way; dry steam between the vats is most convenient, and water heats most evenly, and holds the heat the longest, but is most difficult to control." Steam is the most popular method for heating, and will probably continue so in the large creameries.

*Curd-Knives.*—In Fig. 967 are shown a number of perpendicular and horizontal curd-knives. When the curd has become of the proper consistence, it is cut in half-inch cubes, first by the perpendicular knife, both lengthwise and crosswise, and then with the horizontal knife.

968.



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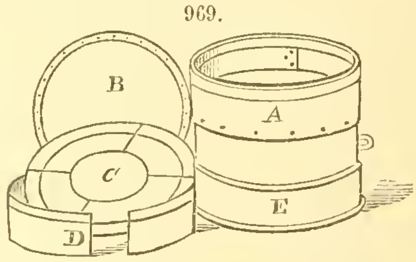
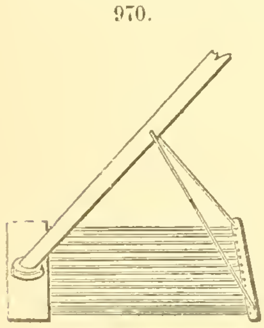
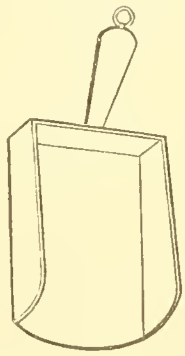



Curd-mills are usually placed over the vats, so that when the curd is ground it falls into the latter. The object is to disintegrate the curd, so that it may be more equally salted.

970.



971.



*Cheese-Press.*—The gang-press is shown in Fig. 968. This press is constructed horizontally, and the cheese is pressed in gangs from 1 to 12 in each press, and in a horizontal position, as shown in the figure. In Fig. 969, *A* is a hoop; *B*, the side of the follower next the cheese, showing the elastic ring, also representing the perforated bottom seen below *E*; *C*, the other side of the follower, showing grooves in which are holes for the passage of the whey; *D*, bandager, on which the bandage is placed, and the bandages inserted in the hoop, the lower edge resting on the ledge seen on the inside of the hoop, nearly the width of the bandage from the top, forming a smooth surface on the inside of the hoop.

In Figs. 970 and 971 are shown a curd agitator and scoop of simple construction, which will need no description. H. A. M., Jr.

DAMPER. A valve placed in an air-duct by which the latter is opened or closed more or less, in order to regulate the air-supply and so increase or diminish the energy of combustion. Dampers are of various forms, usually in the shape of butterfly valves, hinged flaps, or sliding or rotating grates. They bear the same relation to the air-pipe or flue as does the valve or faucet to the duct for steam or liquids. The term "damper" is also applied to the padded finger in a piano movement which comes against the strings and limits the period of the vibrations. (See PIANOFORTE.)

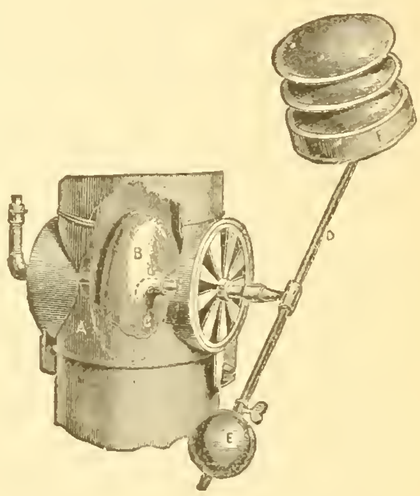
*Dampers for Steam-Boilers.*—The area of a damper depends on the height of the chimney; and where there is only one boiler, it may have the same area as the chimney, if that is properly proportioned to the power of the boiler. (See CHIMNEY.) As an approximate rule, we may give $110 \div \sqrt{H} = A$, in which $H =$ the height of the chimney in feet, and $A =$ the area of the damper in square inches per horse-power; thus, for a chimney 100 feet high, we have $110 \div 10 = 11$ inches per horse-power. The form of damper is arbitrary, and must often be varied to suit the form of the flue; but for ordinary cases we may adopt standard sizes, a convenient proportion being 3 to 1, and thus we have the sizes and powers given in the following table. The powers of other sizes may be easily calculated by the numbers in the fourth line of the table. Thus, say we require the size for a large damper to a set of boilers 300 horse-power for a chimney 100 feet high: the table gives 11 inches per horse-power, and we have $300 \times 11 = 3{,}300$ square inches for the area required; and if the height was fixed at 6 feet, or 72 inches, the width must be $3300 \div 72 = 46$ inches.

*Table showing Sizes of Dampers to Steam-Boilers, with different Heights of Chimney. (From Box on Heat.)*

| SIZE OF THE DAMPER IN INCHES. | HEIGHT OF CHIMNEY IN FEET. | | | | | |
|---|---|---|---|---|---|---|
| | 40 | 60 | 80 | 100 | 120 | 150 |
| | SQUARE INCHES OF DAMPER PER HORSE-POWER. | | | | | |
| | 17.4 | 14.2 | 12.4 | 11.0 | 10.0 | 9.0 |
| | HORSE-POWER OF THE BOILER. | | | | | |
| 6 × 18 | 6.2 | 7.6 | 8.7 | 9.9 | 10.8 | 12 |
| 7 × 21 | 8.5 | 10 | 12 | 13 | 15 | 16 |
| 8 × 24 | 11 | 13 | 16 | 18 | 19 | 22 |
| 9 × 27 | 14 | 17 | 20 | 22 | 24 | 27 |
| 10 × 30 | 17 | 21 | 25 | 28 | 30 | 34 |
| 12 × 36 | 25 | 31 | 35 | 40 | 43 | 48 |
| 14 × 42 | 34 | 41 | 47 | 53 | 59 | 65 |
| 16 × 48 | 44 | 54 | 62 | 70 | 77 | 85 |

Fig. 972 represents an improved form of damper-regulator, in which the lever *D* is the continuation of a siphon pipe *C*, weighted at one end with the weight *E*, at the other end with the metal receivers *F*, and all in connection with the valves in the collar *A*. The action is as follows: With a moderate amount of heat passing up the chimney, the water in the boiler *B* remains at or near the boiling-point, and the valves remain closed; but as soon as the volume of heat is materially increased, steam is generated, which forces a portion of the water through the siphon pipe *C* into the lower metal receiver. The weight of the water overcomes the weighted end, and the disk descends, partially opening the air-valves in the smoke-pipe, admitting a current of cold air, which serves to reduce the force of the draught in like proportion. Any further increase in the volume of heat passing into the smoke-pipe will likewise increase the steam-pressure, forcing a greater weight of water into the receivers, opening the air-valves wider, and reducing the force of the draught to its lowest point necessary for combustion. As soon as the fire is checked and the smoke-pipe cools, the water gradually returns to the boiler, reversing the action.

972.



DAMS. See BARRAGE.

DEFECATING PAN. See SUGAR MACHINERY.

DENSITY. See DYNAMICS.

DERRICK. See CRANES AND DERRICKS.

DEVIL. See PAPER MACHINERY, and INDIA-RUBBER MACHINERY.

DIAMOND. The diamond is the hardest substance in nature; and, in common with some other crystalline bodies, it is harder at the natural angles and edges, and also at the natural coat or skin of the stone, than within, or in its general substance. Its peculiar hardness is probably altogether due to its highly crystalline form, as by analysis the diamond, charcoal, and plumbago are found to be nearly identical; the first is absolutely pure carbon, the others are nearly so.

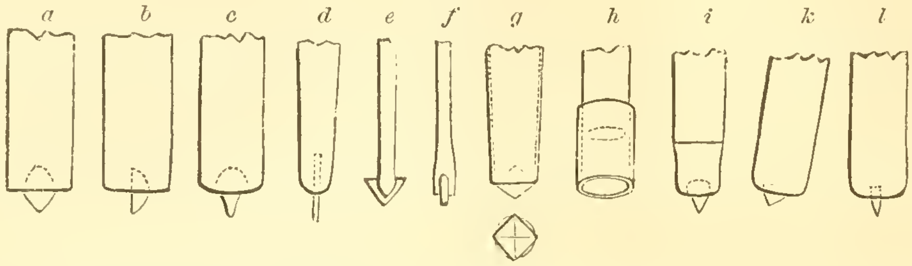
The primitive form of the diamond is that of a regular octahedron; it is like two square pyramids joined base to base; the four sides of the pyramids meet at the angle of 90°, their bases at the angle of 190° or thereabouts. Many of the diamonds merge from the form of the octahedron into that of the sphere, or a very long egg, in which cases, although a disposition to the development of the 6 points, each formed by the meeting of 4 surfaces, exists, they are curiously twisted and contorted. The Count de Bournon published upward of 100 forms of crystallization of the diamond, but the irregular octahedrons with round facets are those proper for glaziers' diamonds.

The extreme point of any diamond may be employed to *scratch* glass with a broad white streak, and detach its particles in a powder, but such glass will break with difficulty (if at all) through such a scratch; whereas the almost invisible fissure, made when the rounded edge is slid over the glass with but slight pressure and almost without causing any sound, is that which produces the effective *cut;* and the cut or split thus commenced will be readily extended through the entire thickness of the glass, when the extremities of the sheet are bent with the fingers or appropriate nippers.

The following figures represent, say two or three times magnified, the forms of diamonds that would be most proper for various tools; but it will be remembered they are only selected as near to the respective shapes as they can be found, either among imperfect diamonds, or from fragments split off good stones in the first stage of their manufacture for jewelry; these pieces are known as *diamond bort.* The diamonds are mostly fixed in brass wires, by first drilling a shallow hole for the insertion of the stone, which is imbedded slightly below its largest part, and the metal is pinched around it. Shellac is also used for cementing them in, and spelter or tin solders may be fused around them with the blow-pipe, but pinching them in annealed brass is preferred. When diamond tools larger than those made of crystals or thin splinters are required, diamond powder is applied upon metal plates and tools of various forms, which serve as vehicles, and into which the particles of diamond powder are imbedded, either by slight blows of the hammer or by simple pressure.

In the construction of jeweled holes, and in similar works, the rubies and sapphires, although sometimes split, are more commonly *slit* with a plate of iron 3 or 4 inches in diameter, mounted on a lathe, and charged on the edge with diamond powder and oil. When sliced, they are ground parallel one at a time on a flat plate of copper (generally a penny piece), mounted on the lathe, and into the turned face of which small fragments of diamond have been hammered; this is called a roughing-mill. A similar plate with finely washed diamond powder is used for polishing them. The rubies are afterward cemented with shellac, on the end of a small brass chuck, turned cylindrical on their edges, and beveled for burnishing into the metal rings. They are also turned concave and convex on their respective faces, the turning tool being a fragment or splinter of diamond, fixed in a brass wire.

973.




In Fig. 973, *a* represents the flat view and *b* the edge view of such a tool, but of the form more usually selected for turning hardened steel, viz., an egg-shaped diamond split in two, the circular end being used with the flat surface upward; the watch jeweler uses any splinter having an angular corner.

The *convex* surfaces of the rubies are polished with *concave* grinders of the same sweeps, the first of copper, the next glass, and the last pewter, with three sizes of diamond powder, which is obtained principally from Holland, from the men who cut diamonds for jewelry, an art which is more extensively followed in that country than elsewhere. The watch jewelers wash this powder in oil, after the same manner that will be hereafter explained in regard to emery.

In drilling the rubies, they are chucked by their edges, and a splinter of diamond, also mounted in a wire, is used. Should the drill be too conical, the back part is turned away with a diamond tool to reduce it to the shape of *c*; and from the crystalline nature of the stone, some facets or angles always exist to cause the drill to cut. The holes in the rubies are commonly drilled out at two processes, or from each side, and are afterward polished with a conical steel wire fed with diamond powder. In producing either very small or very deep holes, a fine steel wire, *d*, is used, with diamond powder applied upon the end of the same, the limit of fineness being the diameter to which the steel wire can be reduced. In drilling larger holes in china and glass, triangular fragments of diamonds are fixed in the cleft extremity of a steel wire, as in *e* and *f*, either with or without shellac. Another common practice of glass and china menders is to select a tolerably square stone, and mount it as at *g* in the end of a taper tin tube, which wears away against the side of the hole so as to become very thin, and by the pressure to embrace the stone by the portions intermediate between its angles. The stone is from time to time released by the wearing away of the metal, but these workmen are dexterous in remounting it; and that the process is neither difficult nor tedious to those accustomed to it, is proved by the trifling sum charged for repairing articles, even when many of the so-called rivets (or rather staples) are cemented in; they employ the upright drill with a cross staff. A similar diamond drill mounted in brass has been used, with the ordinary drill-bow and breast-plate, for drilling out the hardened-steel nipple of a gun, which had been broken short off in the barrel; no material difficulty was experienced, although the stone appeared to be so slenderly held. For larger holes, metal tubes such as *h*, fed with diamond powder, are used; they grind out an annular recess, and remove a solid core. Copper and other tools fed with emery or sand may be thus used for glass, marble, and various other substances. The same mode has been adopted for cutting out stone water-pipes from within one another by the aid of steam machinery.

At *i* is represented the conical diamond used by engravers for the purpose of etching, either by hand or with the various machines for ruling etching grounds, medals, and other works. Conical diamonds are turned in a lathe by a fragment of another diamond, the outside skin or an angle being used; but the tool suffers almost as much abrasion as the conical point, from their nearly equal hardness; therefore the process is expensive, although when properly managed entirely successful.

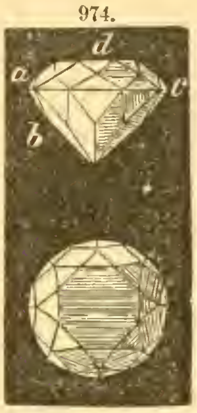
To conclude the notice of the diamond tools, *k* and *l* show the side and end views of a splinter suitable for cutting fine lines and divisions upon mathematical instruments. The similitude between this and the glazier's diamond will be remarked, but in the present case the splinter is selected with a fine acute edge, as the natural angle would be too obtuse for the purpose. Mr. Ross, with a diamond point of this kind, was enabled to graduate ten circles upon platinum, each degree subdivided into four parts; at the end of which time the diamond, although apparently none the worse, was accidentally broken. A steel point would have suffered in the graduation of only one-third of a single circle upon platinum, so as to have called for additional pressure with the progress of the work, which in so delicate an operation is of course highly objectionable.

*Diamond-cutting.*—Of the forms into which the rough diamond is cut, the *brilliant*, Fig. 974, displays the lustre of the stone to the greatest advantage. It is described as obtained by two truncated pyramids united together by one common base, the upper pyramid being much more truncated than the lower. *a* is the crown and *e* the collet, the two principal divisions formed by the girdle *c*. *d* is the table, and the opposite side below, the culasse. The faces are called facets, and, including table and culasse, may number 64. The *rose diamond*, Fig. 975, has a crown, but no collet; that is, one side is flat; and it is usually made from stones and fragments which would not without

loss form good brilliants. Then there are *table diamonds*, which are flat and have little lustre, and *bastard diamonds*, or those of mixed shapes.

In Fig. 976 is represented an enlarged section of the rough gem, showing the grain, along which it may be as cleanly cleft as a piece of wood. The resemblance to the latter substance is increased by the fact that there are so-called knots, which cause a conchoidal instead of a straight clean fracture.

974.

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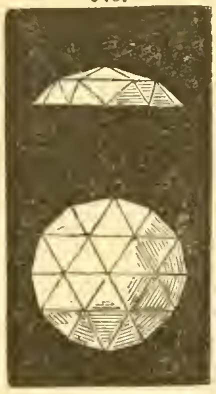

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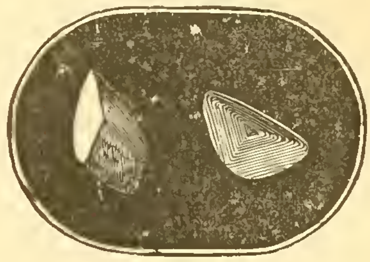


The first process is termed "cleaving." On a small table in front of the workman is a box divided into two compartments, the farthest containing a covered tray for the reception of stones. The other division is made deeper and has a false bottom, being finely perforated. The diamond is secured in a knob of cement (brick-dust and rosin) on the end of a spindle. The fragment of a stone that has already been operated upon is fastened in a second spindle in a similar manner. Next, with an implement in each hand, the cleaver brings the diamonds together, steadying the shanks of his tools against two metal projections on the edge of the box before him. Applying the second diamond to the rough gem, with a quick grinding motion he rapidly cuts a notch in the latter. As hardly any two stones are alike, and no rule can be laid down for the work, some idea may be gained of the consummate skill which enables a man to pick up a tiny fragment, glance at it once, and instantly detect, not only flaws or streaks, but where they are located, in the heart or on the surface; to make up his mind exactly what microscopic pieces must be removed, their size, and how they may be cut to turn them to best account; and, finally, how to so divide the stone as to produce the best color. Placing the spindle containing the gem upright before him, the operator places one of his knives directly over the cleft. The knife used is nothing more than a piece of steel, perfectly flat, with a square edge, and about 6 inches long. It is ground blunt purposely; for if it were keen, the hard stone would quickly turn the edge. Tapping the back of the blade lightly with his iron rod, the artist splits off a fragment, and then melts his cement and removes the parts.

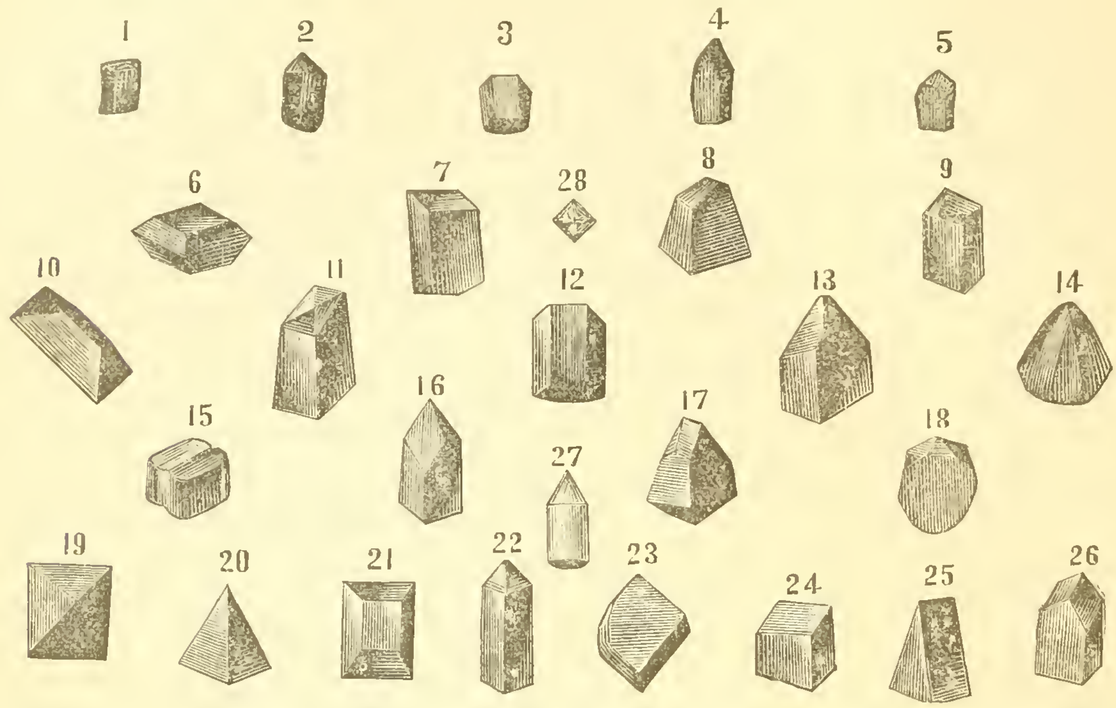
The cutter employs the same form of box as that used by the cleaver, and the diamonds are fastened by cement, as before, in the ends of spindles. The cutter's labor is purely "diamond cut diamond." The stone to be cut is held in its setting firmly in the left hand, while the cutting piece is moved by the right. Both gems are of course affected by the mutual abrasion, but the attention of the workman is directed to but one. Very slowly the faces are ground away; no measurements are taken or angles calculated; the eye is the only guide, and it seems to be a faultless one. As soon as the first stone is finished, the diamond used for cutting it is operated upon, so that diamond No. 2 is, in turn, cut by No. 3, this by No. 4, and so on. At this stage the gems present no different appearance from rough quartz pebbles. The friction dulls them, for they are ground together with considerable force, the workman being obliged to protect his hands by thick coatings against the rubbing action of the tool. An ingenious machine for automatically accomplishing this work was exhibited at the Paris Exposition of 1878. The diamond to be cut is placed in its dopp and fastened in a reciprocating crank-rod. The cutting diamond is secured in an adjustable rest which has an up-and-down motion, and which also, by a worm and pinion, may be rotated in a horizontal plane. A feed-motion is provided, whereby the diamond to be cut is fed up to the cutting diamond. This machine works with considerable accuracy, and is easily managed by a girl.

The diamonds are next set to prepare for polishing. The dopp in which the gem is imbedded is a copper cup about $1\frac{1}{2}$ inch in diameter, provided with a stem of stout wire of the same metal, and filled with plumber's solder. This is filled with solder, and placed in a charcoal furnace. When the solder becomes plastic, the diamond is inserted. The polishers are seated before long tables, on which are swiftly rotating horizontal disks fastened on vertical spindles, the lower ends of which revolve in anti-friction steps at the rate of 2,000 turns a minute. The disks, or *shives*, are circular plates of a composition containing both iron and steel. They are ground in lines, at an angle from centre to circumference, so as to hold the oil and diamond-dust used in the polishing operation. Three diamonds, set as above described, are ground at once by each polisher. The stem of the dopp is fastened in tongs or clamps, the extremity of the latter being supported by legs an inch or so high. Two-thirds of the dust ground off in the cutting is allowed to polish each diamond, and this, mixed with oil, is applied to the stone by quills. The adjusting of the gem on the disk requires wonderful accuracy, in order that exactly the proper facet be ground and no more; for the slightest mistake might cut away an angle and produce serious damage to the stone. So sensitive is the touch of the artist, that he tells by pressing on the stem of the dopp exactly whether it lies true against the shive or not, and by his fingers adjusts the stone over incredibly minute angles and distances. This goes on until each facet is brought to the requisite brilliancy.

*Industrial Utilization of the Carbon.*—The carbon, or black diamond, is used to point edge or face

tools for drilling, reaming, sawing, planing, turning, shaping, carving, engraving, and dressing flint, grindstones, whetstones, emery, corundum, or tripoli wheels, indium, nickel, enamels, crystals, glass, porcelain, china, steel, hardened or otherwise, chilled iron, copper, and other metals. (See ROCK DRILLS, and STONE-WORKING MACHINERY.) In Fig. 977 are represented some of the various forms to

977.




which diamonds or carbons are ground. Points No. 1, 2, and 3 are shaped carbons used for working and turning grind and other kinds of stones, emery-wheels, etc. No. 4 is a diamond-point with angles of 60°, used for dividing on metal or for turning out screw-taps, etc. No. 5 is a diamond barley-corn cutter, used by watch and pencil-case makers, etc. No. 6 is a carbon double-sized trapezoid, used in various positions for marking or working stone. No. 7 is a diamond chisel-point for turning metal. No. 8 is a carbon drill-faced parallelogram for pointing combination drill-heads for stones. No. 9 is a diamond quadrangular prism. No. 10 is a carbon truncated prism for stone. No. 11 is similar to No. 8. No. 12 is a carbon truncated prism for facing or edging ring or cylinder drills, saws, etc., for stone. No. 13 is a carbon quadrangular drill-point for stone. No. 14 is a carbon reamer for stone, etc. No. 15 is a carbon block, used for the same purpose as No. 12. No. 16 is a diamond graver for metal, etc. No. 17 is a flat octahedron carbon drill-point for stone, glass, etc. No. 18 is a flat ovoid used for the same purpose. No. 19 is a carbon tetrahedron, used for the same as Nos. 10 and 12. No. 20 is a pyramidal diamond-point. No. 21 is a carbon truncated prism. No. 22 is a diamond-pointed reamer. No. 23 is a carbon flat-pointed drill. No. 24 is a diamond chisel-point. No. 25 is a diamond double-inclined plane wedge. No. 26 is a carbon quadrangular wedge for turning stone, etc. No. 27 is an acute conical-turned diamond-point for engraving and etching on steel, etc. No. 28 is a diamond in its natural crystallized hexahedron form, as found in the mines. The above illustrated diamond and carbon points or cutters range in size from one-sixteenth to 10 carats each (a carat is equal to 4 grains).

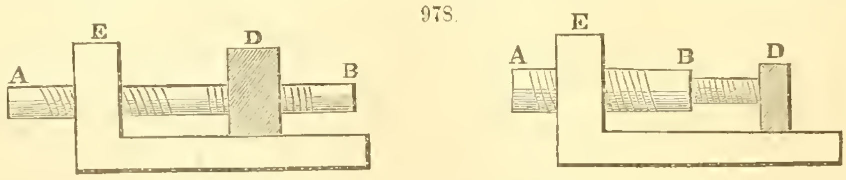
DIAMOND TOOLS. See DIAMOND, ROCK DRILLS, and STONE-WORKING MACHINERY.

DIES. See TAPS, STOCKS, AND DIES.

DIFFERENTIAL PULLEY. See BLOCKS.

DIFFERENTIAL SCREW. A mechanical device for obtaining great pressure through the prolonged action of a small amount of power. Two screw-threads of different degrees of inclination are formed upon the same spindle, *A B*, Fig. 978, the spindle itself passing through two nuts, one of

978.




which, *E*, is part of a solid frame along a groove in which the other, *D*, slides. Let the numbers 5 and 4 represent the pitches of the screws at *E* and *D*. Then, upon turning *A B* once, the nut *D* is carried forward through a space 5, and is brought back again through a space 4; it therefore advances through the difference, 1, of these intervals.

DIFFERENTIAL TACKLE. See BLOCKS.

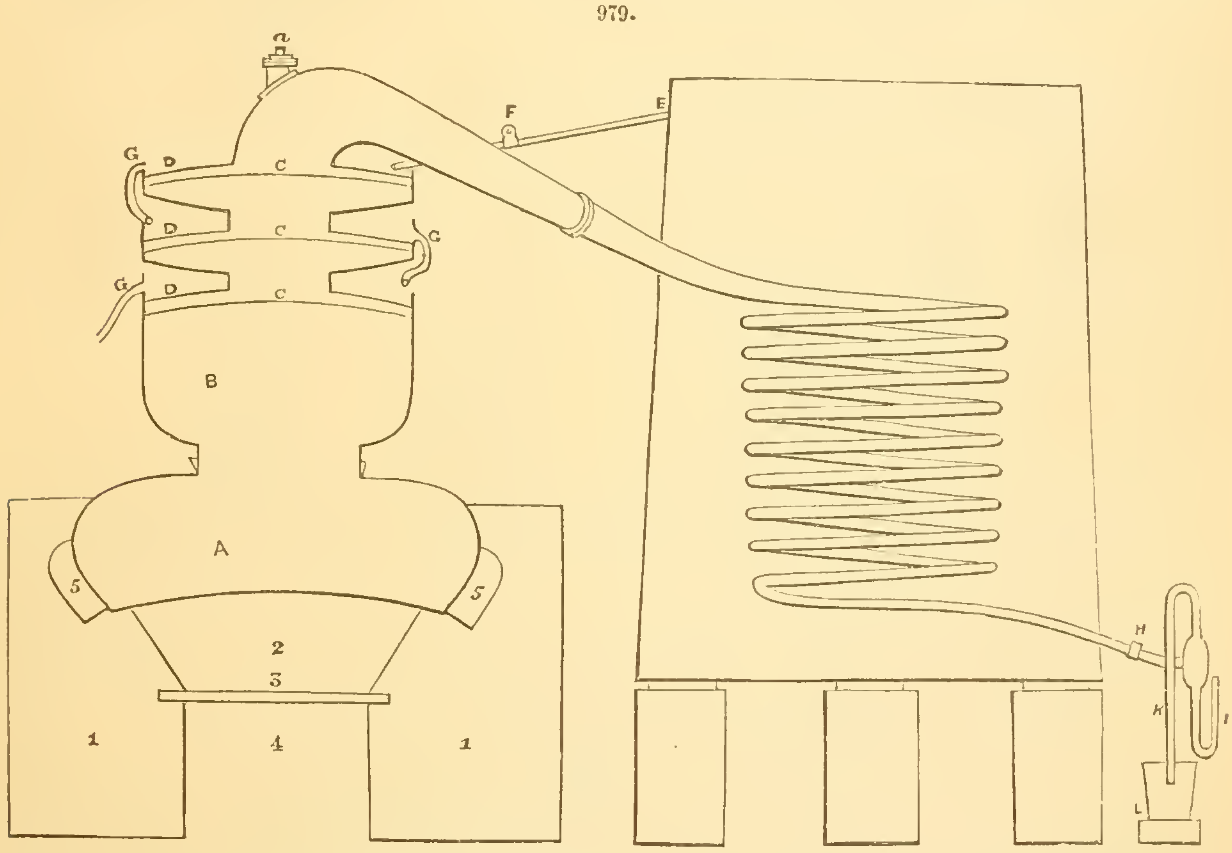
DISINTEGRATOR. See MILLS.

DISTILLING APPARATUS. The vessel used for generating the vapor in distillation, if of large size, is called a *still*. Distillation as carried on by the chemist is usually by means of *retorts*,

and the vessel that receives the distilled matter is called a *receiver;* this is perhaps the most simple method of distilling. The distillation of coal in the manufacture of illuminating gas is conducted in cast-iron retorts, and is an example of this form of distillation.

There are two distinct operations in the production of ardent spirits. The one is the conversion of certain vegetable principles into alcohol, the other the separation of the alcohol from other substances with which it is necessarily blended in its production. The vegetable principle which is essential to the formation of alcohol is sugar, and this is sometimes used directly, as when molasses and like products are subjected to immediate fermentation, or it is indirectly obtained by subjecting amylaceous grains to certain processes by which the starch they contain is first converted into sugar, and the sugar afterward alcoholized. For this latter purpose, the various grains are subjected to the operation of bruising or *mashing*, and infused under constant agitation in a proper quantity of water in the mash-tun. In this way the *wash* is obtained, which is run into the fermenting vats, where, mixed with a small quantity of yeast, it is subjected to the process of fermentation, which requires from 6 to 12 days, the term varying with the mass of liquid and the temperature of the atmosphere. As the fermentation progresses, the wash attenuates; when this attenuation reaches the maximum, the wash is drawn into the still and subjected to heat. By this means the more volatile matter, passing over first, is condensed in the worm, and yields spirit. In general, the wash is first subjected to distillation, from which a weak spirit is obtained; then this spirit is redistilled, from which proof spirits are obtained; the stronger spirits, being the most volatile, are the first to pass over.

979.

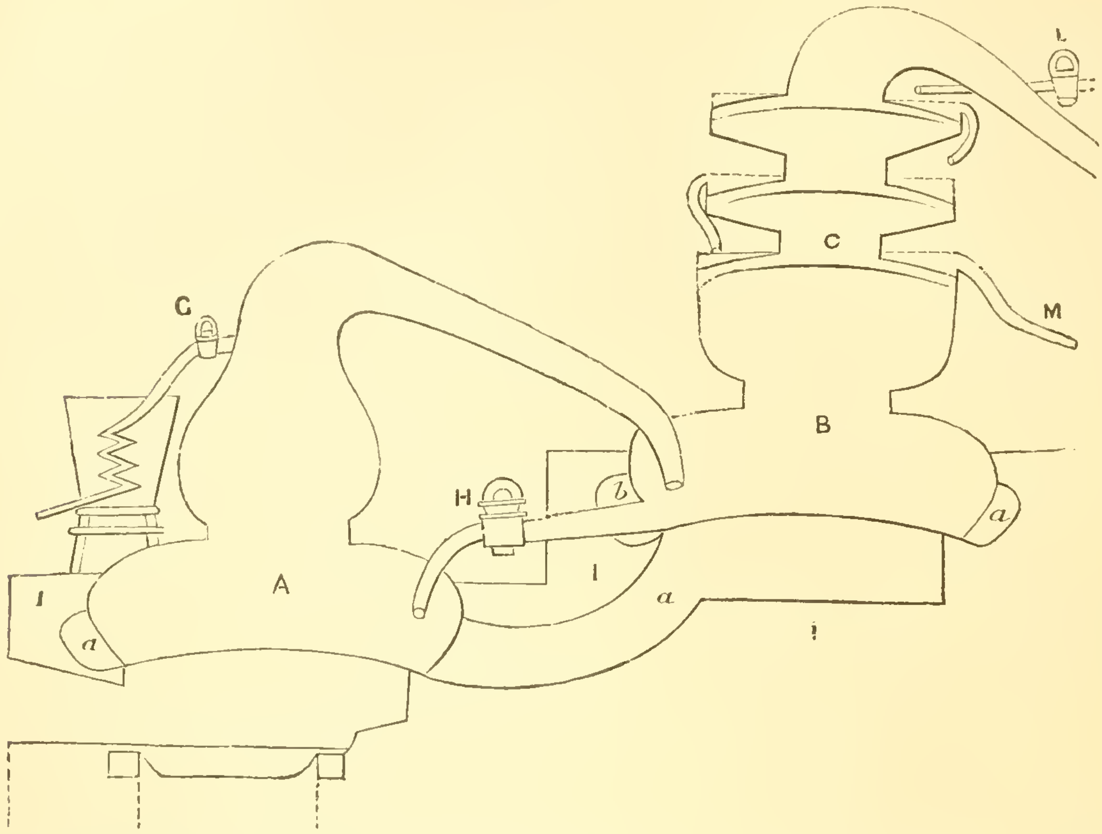



Of stills there is almost an endless variety, differing not in essential principles, but in detail. We instance one of the earliest improved stills, that invented by Corty, and afterward much simplified by Messrs. Shears & Sons.

Fig. 979 is a representation of this still. *A* is the body of the still, into which the wash is put; *B* is the still-head; *C C C* are three plates of copper fitted into the upper part of the boxes *D D D*, which are kept at a regulated temperature by water being conducted over their outer surface, by means of the pipe *E* and the distributing pipes *G G G*. The spirit vapor then rising from the body of the still meets a check at the lowest plate *C*, by reason of the coolness occasioned by the water; this condenses the grosser part of the vapor and throws it back, while the lighter proceeds on to the second plate *C*, where a further coolness condenses another portion of the vapor, leaving a much purer spirit to encounter the increased coolness at the third plate *C*. Here the last separation takes place; the aqueous and oleaginous particles, being unable to sustain the temperature maintained, fall back condensed, and only a very strong spirit passes over in the gooseneck. By means of the cock *F*, in the pipe *E*, the supply of water to the boxes *D* can be very exactly regulated; and, as a natural consequence, the temperature can be very accurately adjusted. If the temperature of the upper box be kept at 174°, for example, the alcoholic vapor which passes over will be composed of 90 per cent. of pure alcohol, or 65 over proof; but with a temperature of 194° F. the vapor will contain only 66 per cent. pure alcohol, or 30 over proof. *a* is a screw-cap, through which a jet of steam or water may be sent to clear away the deposits, which otherwise will more or less accumulate on the upper surfaces of the plates *C*. At the lower end of the worm-pipe is affixed, by means of the brass swivel-joint screw *H*, a gas apparatus. The pecu-

liar form of the pipe *I*, into which the spirit runs from the worm, causes it to be filled shortly after the still commences working; while the other branch pipe *K* rises to some height, then returns, and is immersed in the small box *L* to the extent of about 2 inches in water. The gas from the still escapes by this pipe through the water, as the pressure can be but trifling. It is held that, by means of this gas apparatus, the distillation proceeds in a partial vacuum, and that thereby

980.



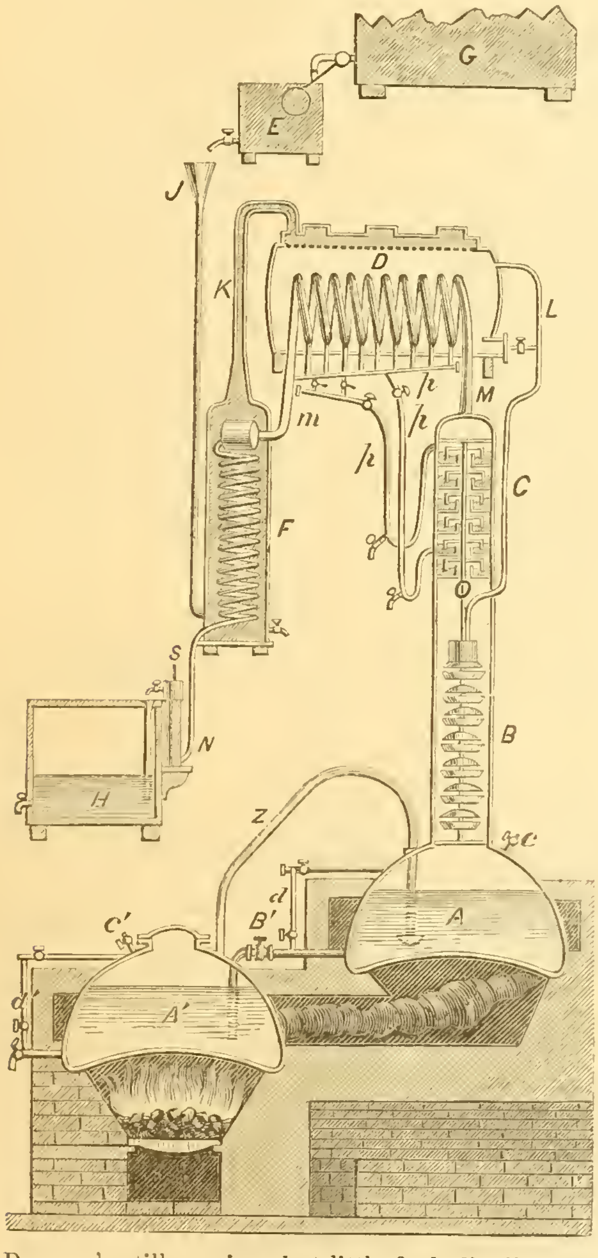

there is a great economy in fuel. As the spirit enters the worm at so much lower a temperature than in the old stills, so much water is not required to cool the spirit vapor as would be otherwise. A still of 400 gallons is said to work off four to five charges in the day of 12 hours, yielding a spirit on an average of 35 per cent. over proof; which, for rum, is considered the most advantageous strength to run it at.

Fig. 980 is another arrangement of the same kind of still, being the addition of the common still *A* to the patent still *B*. In this case the contents of *B* are drawn down from time to time into *A*, and those of *A* run off as dunder, the spirit from *A* being conducted into *B*. One fire heats both stills; and it is stated that, by the general adaptation and arrangement, a very large quantity of fine spirit is produced by the consumption of a very inconsiderable amount of fuel.

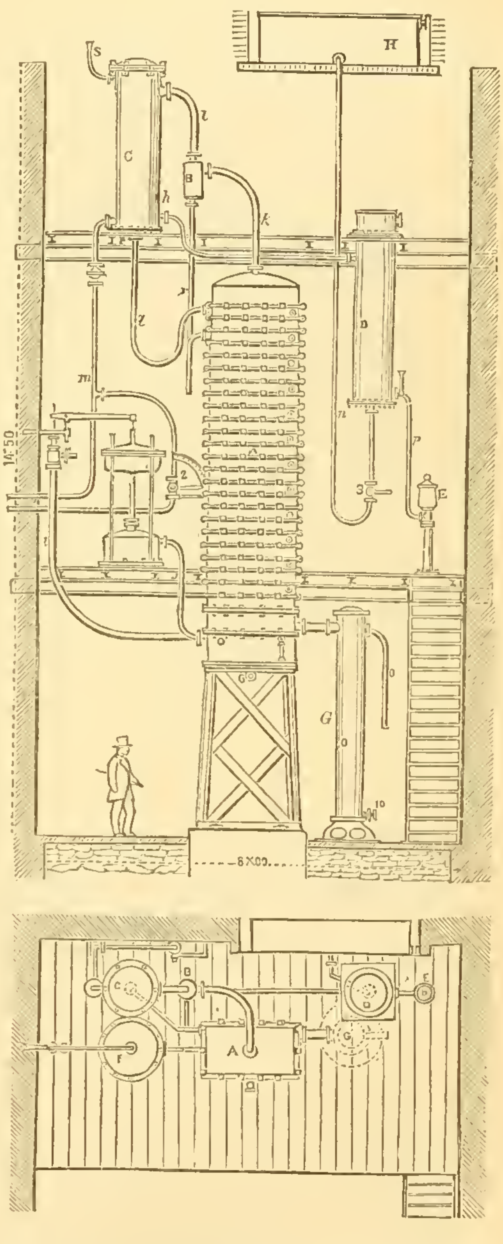
In Fig. 981 is represented Derosne's still. It consists of two boilers, *A A'*; a first rectificator, *B*; a second rectificator, *C*; a wine-heater, *D*, containing a dephlegmator; a condenser, *F*; a supply-regulator, *E*, for controlling the flow of wine from the reservoir *G*, which is accomplished by means of a floating ball. The still is worked in the following manner: The boilers are about two-thirds filled with wine, or the liquor to be subjected to distillation, through the cocks *c c'*. The proper quantity is indicated by the glass gauges *d d'*. Wine from the reservoir *G* is then let into the funnel *J*, by which the condenser *F* and the wine-heater *D* are filled. On the application of heat the low-wine vapors pass from the lower into the upper boiler through the pipe *Z*, the extremity of which is enlarged and perforated with small holes. Here the vapors are condensed, increasing the strength of the wine in the upper boiler, and consequently lowering its boiling-point. The vapors ascend into the rectificators *B* and *C*. The lower rectificator, *B*, contains a number of shallow pans perforated with holes, and a number of spherical disks, also perforated with holes, placed above them, in pairs, the convexity of each disk being upward, and receiving the drip of the shallow pan next above it. This drip is produced by warmed wine which flows from the wine-heater through the pipe *L*. By these means the vapors ascending from the upper boiler have their more watery portions condensed, while the alcoholic vapor continues to ascend. The dripping wine also has a portion of its alcohol expelled in the form of vapor, which ascends with the vapor coming from below into the upper rectificator through the orifice *O* in its bottom. This upper rectificator communicates through the tube *M* with a worm (which is the dephlegmator) in the wine-warmer *D*, the worm ending in the tube *m*, which again terminates in the worm contained in the condenser *F* through a cylindrical connection in its upper part. The worm in *F* terminates in a small vessel, *N*, which is furnished with an alcoholometer. The alcohol in *N* flows from its upper part into the cistern *H*. The upper rectificator *C* is divided into a number of compartments by as many horizontal partitions, each disk having an orifice in its centre, like the orifice at *O*. To each of these orifices on the upper side of the partition is adjusted a short open vertical tube. A short distance above each tube is placed an inverted pan, having its edges descending about three-fourths of an

inch below the level of the upper orifice of the tube. As the vapor ascends from the lower rectificator into the upper one, a portion of it condenses and collects upon the bottom of the compartments, until it rises slightly above the edges of the inverted pans and nearly to the upper orifices of the tubes. When this takes place the vapor can only pass upward by forcing its way under the edges of the pans, by which means the more watery portion is still further condensed, the more alcoholic vapor, having a higher tension, retaining its gaseous form, and passing on through the tube *M* into the dephlegmatory worm in the wine-heater, there to be partially condensed; which process heats the wine surrounding the worm. A phlegma collects in the lower convolutions, which may be drawn off by means of the pipes *p p p*, and transferred at pleasure either into the tube *m* or into the upper rectificator. The purer alcoholic vapors which arise pass through the dephlegmator into the condensing-worm in the condenser *F*, whence they flow in liquid form into the vessel *N*, and thence into the cistern *H*. The strength of the alcohol produced by this still depends upon the number of windings of the dephlegmator, and the number of partitions in the upper rectificator.

981.




982.



Derosne's still requires but little fuel, distills rapidly, and yields a good spirit, which may be varied in strength at pleasure; but it is rather complicated, and may with advantage, especially when spirits of only one strength are required, be replaced by a simplification of it, devised by Laugier.

In Fig. 982 is represented the Savelle still in Springer & Co.'s great spirit and yeast manufactory at Maisons-Alfort, near Paris, France, which is said to be capable of utilizing daily 55,000 lbs. of barley, rye, and corn, mixed in equal proportions.

In order to obtain regular working with such large quantities of material, two conditions have to be fulfilled: 1. Perfect cleanliness throughout the whole apparatus, and the avoidance of any stoppage in the inner system of tubes; 2. The complete separation of the liquids produced.

The first condition is substantially obtained by the swift passage downward of the material subjected to distillation. Having to travel, in passing through the apparatus, 410 feet, it accomplishes the descent in 6 minutes. This gives a speed of 13.65 inches per second, and it is easily seen that with so rapid a movement interior stoppages are nearly impossible.

29

Each section of the distillation column is provided with five bronze observation tubes, which allow of an examination of the interior without interruption of the working. The second condition, which relates to the separation of the liquid, is well fulfilled. The liquid subjected to distillation, which, as above stated, forms a continuous stream 410 feet long, is traversed in every direction by the steam, which carries with it the alcohol formed. The intimate commingling of steam and liquid to be distilled causes a complete absorption by the former of the alcohol contained in the latter. Besides this, the operation of distillation is hastened by the preparatory warming apparatus, provided with large heating surfaces, which utilizes the lost heat of the mass of alcoholic steam issuing from the distillation column, and therefore saves a good deal of fuel. As there is no stoppage in the working, it is necessary that a complete separation of the alcohol should take place regularly, and that none should be lost in the residuary liquors, which run out from the base of the column. This result is assured by the steam-regulator, which maintains constant working conditions. Everything has been arranged so that the matter to be distilled should be kept as long as possible in contact with the steam. The disposition described induces an energetic separation of the contents of the material to be distilled, facilitates the departure of the subsidiary products, gives a working season of eight consecutive months, and allows of a passage through the apparatus of 15,400,000 lbs. of material without any cleaning being needed.

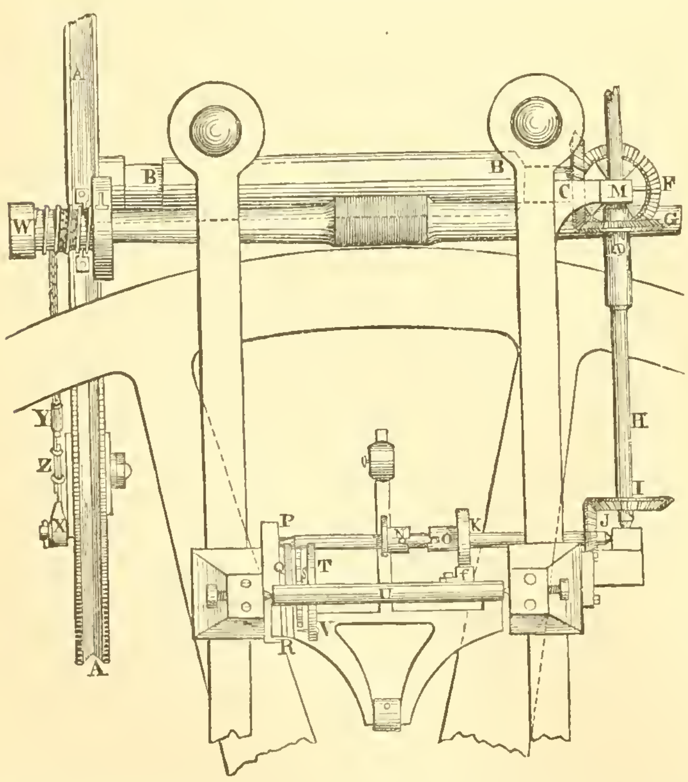
The material to be distilled is first carried by the feeding-pipe *m* into the alcohol-warmer *C*, which, as above stated, transmits to it the lost heat of the column below, thereby partially condensing the alcoholic vapor. After this preparation it passes by the pipe *k* on to the upper surface of the rectangular copper distillation column *A*, which is composed of 25 rectangular sections, bound together by cast-iron clamps, and supported on a framework of iron. In this column the distillation and gradual and methodic enrichment of the alcoholic vapors take place; here the material spreads in thin layers traversed in every direction by the steam brought in by the pipe *i*, and the introduction of which is regulated by the admission-valve of the steam-regulator *F*. A constant temperature is maintained by this latter, and the feeding is regulated by the screw admission cock 2. The foam-breaker *B* stops and returns to the column the substances carried over by the current of alcoholic vapor passing to the alcohol-warmer. The tubular cooler *D*, arranged in compartments, receives cold water from the reservoir *H* by the pipe *n*, and communicates with the graduated gauge and discharge *E*, which measures the flowing of the phlegm. The condensation, which is partially accomplished in the condenser or alcohol-warmer, is finished in the cooler *D*. The large cylinder *G* is used for the reception from the column, and drawing off by means of the conduct *o*, of the residuary products; *j* is the delivery-pipe of the regulator *F*; *h* and *l* are tubes which carry the alcohol from the distillation column to the foam-breaker and alcohol-warmer; *r* is the return-pipe from the foam-breaker to the column, and *s* the air pipe of the alcohol-warmer.

DITCHER. See Agricultural Machinery.

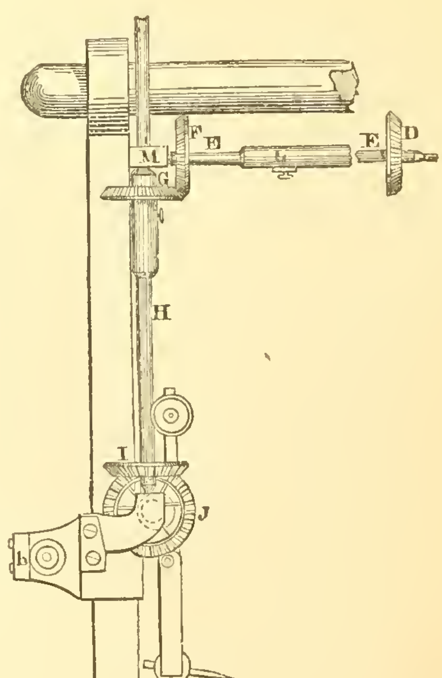
DIVIDERS. See Compasses.

DIVIDING MACHINE. An apparatus used for marking the graduations of, or dividing, astronomical, geodetical, or other mathematical instruments, enabling the same to be accomplished automatically, and with great exactness. Figs. 983, 984, and 985 represent the dividing machine used in the United States Coast Survey Office, and rendered automatic by the late Mr. Joseph Saxton.

983.




984.

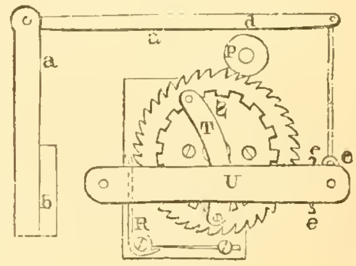



The machinery for rendering the dividing machine automatic consists of a brass wheel *A*, about 20 inches in diameter, mounted on the axis *B*, Fig. 983. One of the arms of the wheel *A* has a slit

extending from near the centre of the rim; in this slit is fixed the crank-pin so that it can be placed at any required distance from the centre. On the edge of the wheel is turned a groove, in which runs a cord for driving the wheel. On the other end of the axis is fixed the wheel *C*, which is geared into the wheel *D*, on the lower end of the vertical shaft *E*, Fig. 984. On the upper end of the same shaft is another wheel *F*, geared into the wheel *G*, on the horizontal shaft *H*. On the end of the shaft *H* is a wheel *I*, which gears into the wheel *J*, on the axis *K*. The wheels *C*, *D*, *F*, *G*, *I*, and *J* are all bevel-wheels, having the same number of teeth (60), and work into each other at right angles.

The shaft *E* has on it a sliding-joint *L*, for altering its length; the shaft *H* is turned and ground of uniform thickness, so that it may slide accurately through the socket of the wheel *G*, and also through its bearing at *M*, in which it turns. The axis *K* has on it two eccentrics, *N* and *O*; *N* to raise the tracing-point, and *O* to move it horizontally. One-half of the circumference of *N* is concentric with the axis on which it turns, so as to keep the point up while the crank-wheel moves half a revolution, and is moving the dividing plate. The other is eccentric to the axis about one-tenth of an inch, so as to let the point rest on the circle while it is making the division. The eccentric *O* has about one-eighth of its circumference concentric to the axis; the rest is described from a point about one-eighth of an inch from the centre. *N* and *O* must be fixed on the axis with regard to each other, so that *N* will raise the point before *O* begins to move it back, and both with regard to the crank-wheel *A*, so that the point will be raised before the crank begins to move the dividing-plate, and keep it up until it is done moving, and *O* has moved the point back, and then let it down before *O* begins to let it return. The axis *K* has also on it, near the end, a small cog *P*, to shift the ratchet-wheel *Q* one tooth every revolution of *K*. The ratchet-wheel has 60 teeth, and is kept in its proper position by the detent spring *R*. In front of the wheel, and fastened to it by two screws, is a circular plate *S*, Figs. 983 and 985, with 20 notches in its edge, the deepest one for the longest line, or 5°, the next for 30′, and the shallowest for 15′, and the edge of the plate for the 5′ lines.

985.




The segment *T*, Figs. 983 and 985, is fixed on the vertical part of the tracing-frame *U*, and has a pin in the end at *V*, of such a size that it can drop into the notches in *S*, as they are brought under it by the revolutions of the ratchet-wheel, and so regulate the length of the division lines. The time of raising the ratchet must be when the stop-pin is raised out of the notch, by the motion of the traces backward. To give motion to the screw, a stout fusee-chain is used, one-eighth of an inch broad and one-fourteenth of an inch thick, which answers well; one end is attached to the ratchet-barrel *W*, round which it is wound five or six turns; the other end is attached to the crank-pin *X*. Near the lower end of the chain, at *Y*, is a small tube, containing a strong spiral spring, arranged like the common spring weighing-machine, but having a motion of only about one-eighth of an inch; the spring must be so strong as not to give by the force required to turn the screw, but only to give a little when the ratchet comes up to the stop, and the crank is just passing the lower centre. Between the spring and the crank-pin is an arrangement for lengthening or shortening the chain, when it is arranged for making a larger or smaller division; for this purpose, two pieces of brass wire, about 6 inches long, having a screw cut on them their whole length, and each filed away one-half, and two small milled nuts, tapped with the same thread, are run on each; the two wires are laid together, and the nuts screwed up until they embrace both wires, as shown at *Z*, Fig. 983.

The crank-pin is fixed on a slide, projecting beyond the nut which fastens it, so that it may be extended, if necessary, beyond the circumference of the wheel; or by reversing, it may be brought quite to the centre. When the divisions are to have the long end toward the centre, a jointed lever, as shown at *a*, Fig. 985, is used. It is screwed fast to the cross-bar *b*, Figs. 984 and 985, directly over the eccentric *O*, and connected to the vertical frame *U* at *e*, and the stop-pin *V* is shifted to the other end of *T*; and the abutting piece *f*, on *U*, is to be removed, when the eccentric *O* will act against the lever *a* at *d*, and move the point in an opposite direction. The tracing-frame is made to follow the eccentric, by a weight and cord passing over a pulley and hooked to the vertical part of the tracing-frame at *e e*, Fig. 985.

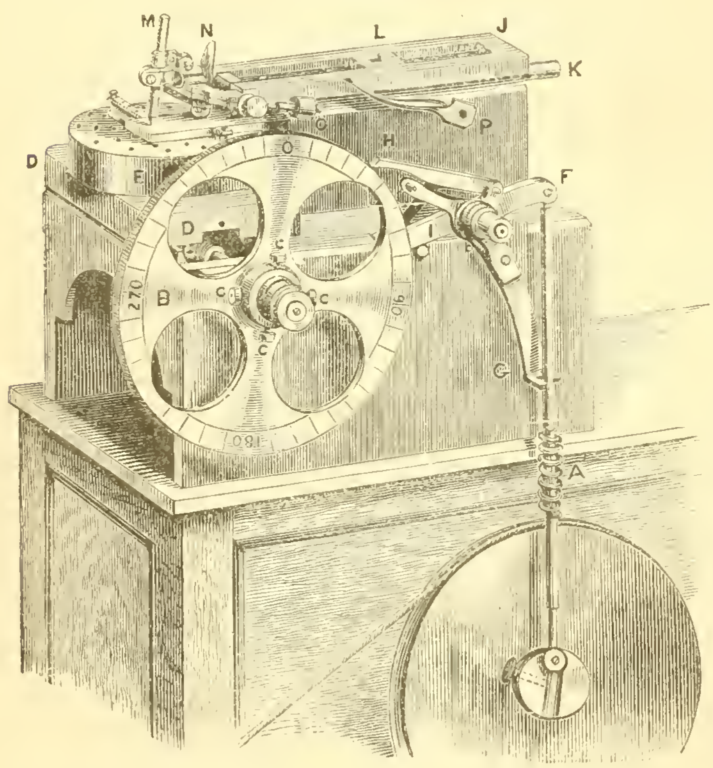
When the adjustment is made for dividing with the long end of the division lines toward the circumference of the circle, all the wheels connecting the axis *K* with the axis *B* should be marked with a dot on the tooth and space in which it works, and a line should be drawn on the shafts *E* and *H*, and a corresponding mark on the sockets through which they pass, so that they may always be fastened in the same position. The axis *K* should have two short pins fastened on it, and notches in the ends of the sockets *N* and *O*, to fix them in their proper position when the lines are toward the circumference or centre, as the case may require. The slit in the crank-wheel *A*, in which the crank-pin is fastened, should also be graduated, showing the distance of the pin from the centre, for each degree, minute, and second that may be required in dividing.

By marking the position of each part of the machine in this way, much time and trouble will be saved in making the necessary changes for different kinds of dividing, whether it be in the number or the direction in which the long lines are to be extended. The tracing-point should be adjusted so as not to be raised more than about the thirtieth of an inch, or it will be liable in descending to make a small dot at the commencement of each line, which would injure the appearance. In the drawing, the eccentric *N* is represented as acting on the tail of the tracing-frame, but it is better to make it act on a steel pin in the side of the tail.

By this arrangement of the crank for turning the dividing-screw, the stops of the ratchet are brought in contact when the crank is passing its centres, and the motion of the screw is so slow that it is not possible for the stops to strike so hard as to do any injury, and the dividing may be done with great rapidity.

*Rutherfurd's Ruling Engine.*—One of the most accurate and delicate dividing machines yet devised is the ruling engine contrived by Mr. L. M. Rutherfurd of New York, for making gratings of fine lines on glass, for use in lieu of prisms in the spectroscope. The apparatus is represented in Fig. 986. On a hollow cast-iron block are cut, at right angles to each other, two V-shaped guides. On one of these guides slides the iron plate *D*, moved by means of a screw acting in a nut attached to its under surface. On this plate is fastened the plane of glass or speculum metal which is to be ruled. On the other guide slides the plate *L J*, having a reciprocating motion given to it by a lever, the action of which will be described further on. To this plate is attached the tool-holder carrying the diamond-pointed cutter. The motive power of the machine is a small turbine, from which passes a cord around the driving-wheel. On this driving-wheel is a pin to which is jointed the connecting-rod *A F*. This connecting-rod is hollow, and in it moves a rod which is constantly pressed toward the pin on the driving-wheel by the spring shown at *A*. When the rod *A F* moves upward, the arm *F I* oscillates on its rocking shaft (the end of which is seen in the figure, projecting horizontally), until the end *I* of this arm comes against the fixed pin placed under it, and in contact with which it is shown in the drawing. Just before this upward movement of the rod *A F* begins, the pawl *H* falls into a notch on the wheel *B*, which is attached to the screw of the engine, and during the upward motion of the rod *A F* the pawl *H* presses against the notched wheel and rotates it a definite fraction of an entire revolution. The pawl *H* having completed its "throw," the crank-pin on the driving-wheel passes its upper centre, and then the slotted lever *G* lifts the pawl out of the teeth of the wheel *B*, so that no jarrings or tremors are given to the machine while the pawl is retreating to take a fresh hold on the feed-wheel *B*. A pin attached to the connecting-rod passes through a slot in the tube *A F*, and serves to hold the two together when the rod is making its downward motion.

986.




The amount of rotation to be given to the feed-wheel *B* is regulated by rotating to the right or to the left the collar on the rock-shaft, to which the pawl *H* is jointed. Directing attention to the plate *L J*, to which is attached the cradle *N* carrying the diamond-pointed rod *M*, we observe at *K* the right-hand end of a rod the extremities of which pass through holes in the iron frame of the engine. This rod is moved parallel to the V-guide of the plate *L J* by means of an oscillating lever which works in a vertical slot attached to the rod *K*, and is fixed on the same rock-shaft which carries the lever *F I*. Projecting upward from the rod *K* is a short rod whose end is shown at *L*. This rod moves in a short slot cut in the direction of the length of the plate *L J*, as shown in the figure.

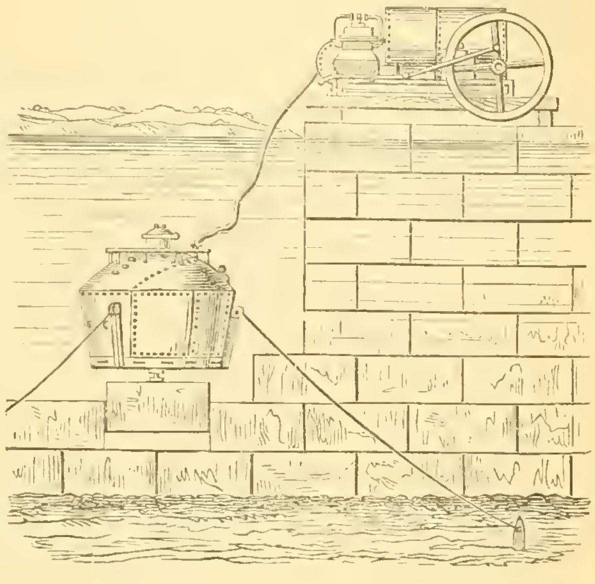
The action of the cutting point of the tool *M* can now be explained. While the pawl *H* is rotating the feed-wheel *B*, the rod *L* presses against the left-hand end of its slot and moves the slide *J* from right to left. The plate *J* cannot move, as above indicated, until the rod *L* touches the left-hand end of its shot; and when it reaches this position the left-hand end of the rod *K* has moved to the left sufficiently to press against the lower point of the cradle *N*, and hold the diamond-pointed tool *M* elevated above the plate of glass or speculum metal during the entire left-hand motion of the plate *J*. When the end *F* of the lever *F I* descends, the rod *K* moves from left to right, and the projecting pin has to move up to the right-hand end of its slot before it can push the plate *J* to the right. During this motion of *L* in its slot, the left end of the rod *K* has allowed the diamond-point on *M* to rest on the glass plate, so that before the plate *J* begins its right-hand motion the diamond-point is at rest on the plate to be ruled. The plate *J* now moves to the right, and the diamond-point cuts a line. But the diamond-point is lifted, before the right-hand motion of the plate *J* ceases, by the side-arm *O* of the cradle *N* coming against the inclined surface of the side-piece *P*. The diamond is thus raised, and is held in this position by the depression of *O* against *P* until the left-hand end of *K* has moved up to the cradle and holds the tool elevated during the motion of the plate *J* to the left. After this motion has ceased, the diamond is lowered to the glass plate, and another cut is made; and so on, the machine working automatically until the plate is ruled. The pitch of the screw is one forty-eighth of an inch; hence, by knowing the fraction of the revolution of the screw made between two contiguous cuts, we know the distance, in fraction of one forty-eighth of an inch, separating the centres of two contiguous lines on the grating. The diameter of the feed-wheel *B* is 6 inches, and from this dimension the reader may estimate the size of the other parts of the engine.

An accurate dividing engine by J. Salleron of Paris is owned by the Stevens Institute of Technology. Ingenious machines are used by engravers for ruling tint-lines on boxwood. (See "The Minute Measurements of Modern Science," Mayer, *Scientific American Supplement*, Vol. III., No. 56.)

DIVING. The necessity for the manual execution of engineering operations under water, and the desire to obtain cargoes of vessels, etc., which have become submerged, have led to the invention of various apparatus whereby men may safely descend to moderate submarine depths. Devices for this purpose may be divided into two classes, diving-bells and diving-armor.

1. *Diving-Bells.*—The principle of the diving-bell is seen in pressing any vessel like a tumbler, mouth downward, into water. The air within the vessel prevents the water from rising and filling it, but the inclosed air is made to occupy less space as the pressure is increased with the augmenting depth of water. The most practical form of diving-bell is called the "Nautilus," Fig. 987. This is a sort of submarine boat, having chambers in its walls, said chambers being connected near the bottom of the pipe, which opens by a cock outward to the external surrounding water. An opening in the bottom of the machine is closed by movable doors. The chambers are likewise connected at top by a smaller pipe, which opens through the top of the machine, and to which opening is affixed a flexible pipe, with coils of wire spirally inclosed. Branches on this latter pipe also allow communication with the larger or working chamber. At the surface of the water is a receiver, to which is attached a hollow drum or reel, to the barrel of which is affixed the other end of the flexible pipe leading to the top of the nautilus. In connection with the receiver (Fig. 987) is a powerful air-condensing pump. The operator enters the machine through the top, which is then closed. To descend, the water-cock is opened, and the external water flows into the chambers; at the same time a cock on a pipe opening from the chambers outward is opened, in order that, the air escaping, an uninterrupted flow of water may take place into the chambers. The weight of water entering causes the sinking of the machine. As soon as the latter is fairly under water, in order that the descent may be without shock, the water-cock is closed. The receiver at the surface being previously charged by the air-pump to a density somewhat greater than that of the water at the depth proposed to be attained, one of the branch cocks on the pipe, connecting the chambers at top, is opened, and the air rushes into the working chamber, gradually condensing, until a density equal to the density of the water without is attained. The bottom is then removed, and communication is made with the under surface, on which the nautilus is resting. In order to move about in localities where the tides or currents do not affect operations, it is only necessary for the workman to step out of the bottom of the machine, and, placing his hands against its sides, to push it in any direction. Where currents or tides exist, it becomes necessary to depend upon fixed points, from which movements may be made as desired. This is accomplished by placing in the bottom of the nautilus stuffing-boxes of peculiar construction, through which cables may pass over pulleys to the external sides, thence up through tubes (to prevent their being worn) to and over oscillating or swinging pulleys, placed in the plane of the centre of gravity of the nautilus, and thence to the points of affixment respectively.

987.

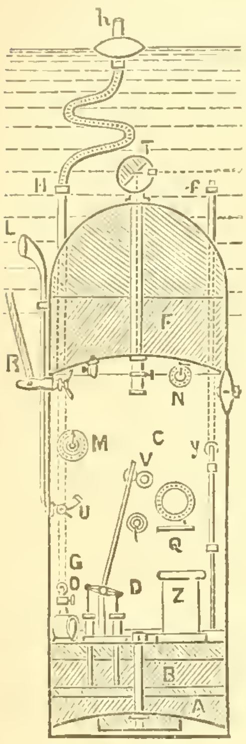


Toselli's navigable diving-bell or marine mole, Fig. 988 A, is a kind of turret divided into four compartments. The bottom division, *A*, contains lead, and serves to hold the bell in a vertical position. *B* can be filled with water by opening a cock communicating from without, or may be rendered entirely empty by aid of the pump. Consequently this chamber serves to augment or diminish the weight of the machine, and to determine its up and down travel, serving the same purpose as the natatory vessels in fishes. In the large compartment *C* the operator and the observer are stationed; and, finally, *F* is a reservoir into which air is compressed in a quantity sufficient to last during the time which the bell is to be submerged. *I* is a cock which admits air from this chamber into the main compartment. *G* is the pipe for carrying off the foul atmosphere, which communicates with the tube *H* and a float. The latter has a valve, *h*, to prevent entrance of water. The bell has a rudder and a screw not shown in the illustration, the screw being worked by a hand-crank by one man, and driving the machine at the rate of about 25 feet per minute. *M* is the manometer, which indicates exterior pressure, and hence the depth of submersion. *N* is another manometer, which shows the pressure of condensed air in the chamber *F*. *R* is a life-line, connecting the bell with the ship. This contains a wire, by means of which telegraph dispatches may be sent to the instrument *Q*. *U* is the manhole, allowing access to the interior of the machine, and closed with a double door. *V* are heavy glass deadlights, and *Z* is a seat.

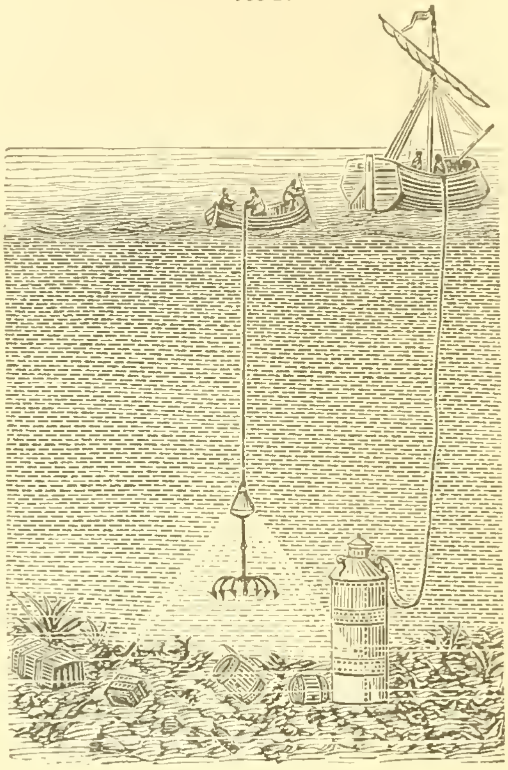
Should the tube *H*, which carries off foul air, break or choke, water would be at once pumped out of *B*, the bell would ascend, and meanwhile the bad atmosphere would be allowed to escape through the extra pipe *f*. In case the electric wire in the life-line should part, preventing the passage of signals, the machine would again ascend, and communicate with the vessel through the speaking-trumpet *L*. If the line remained intact, the bell could be instantly hauled to the surface by those on the ship, in case of a breakage of the hydraulic pump, on signal being transmitted. If pump, wire, and life-line should all break down at once, then the operator would unscrew a nut and free the lead underneath, when he would immediately ascend to the surface. Finally, if by some extraordinary circumstance the ship should break the line and lose sight of the bell, or if the vessel itself

should sink, the operator would first, by unscrewing a nut within, cast his bell loose from the life-line, and would then ascend. As soon as he reached the surface, he would be enabled to view his surroundings by means of a camera obscura at *T;* and, by revolving the same by its tube, he could

988 A.




988 B.



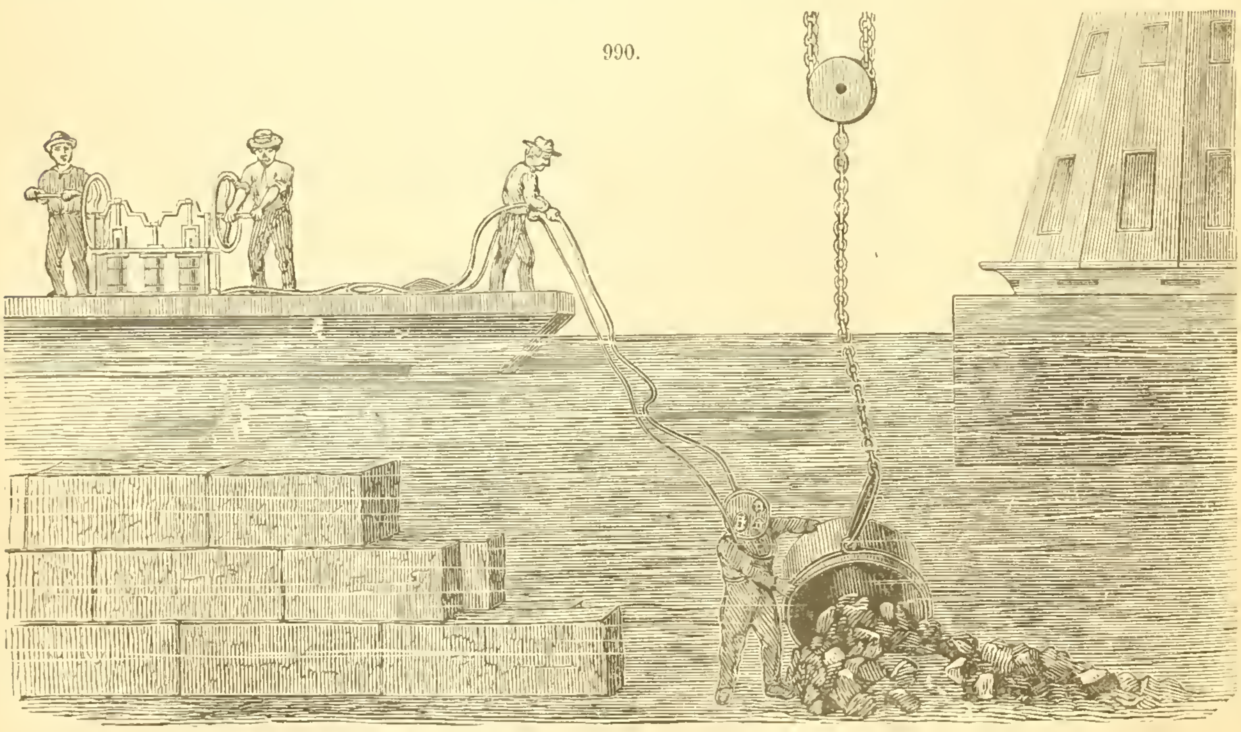
989.

sweep the entire horizon. Having determined his course, he could then proceed in the proper direction by means of the screw and rudder.

The mode of using this bell in connection with a grapnel, the latter provided with an electric light for illuminating the depths, is represented in Fig. 988 B.

*Diving-Armor.*—The diving dress or armor used at the construction of the pier foundations in New York harbor is illustrated in Fig. 989. It consists of a copper helmet, tinned inside, and supplied with thick glass windows and a copper breastplate, which has a collar, to which the helmet is readily adjusted. The helmet is large enough for considerable rotation and lateral motion of the head, and allows the air which is forced into it to be so diffused as to be breathed without inconvenience. The breastplate permits a free expansion of the lungs, and sufficient motion to avoid con-

990.



straint of the muscles. To the lower part of it is attached an India-rubber dress, having a body, legs, and arms; shoes are fitted on, and the whole is impervious to water. The central window of the helmet can be readily removed without removing the helmet. Leaden weights are attached to the waist

and soles of the shoes to enable the diver easily to maintain an erect position when standing or walking upon the bottom. A pump, shown in Fig. 990, which is usually supplied with three cylinders, pumps air through a flexible but strong India-rubber tube into an opening in the back of the helmet, which leads through a flat channel to the frontal portion, where it is delivered against the glass windows, thus serving not only to supply the lungs of the diver, but to clear the moisture from the inner surface of the windows. The air finds its exit also at the back of the helmet. The air from the pump is free to pass down the waist and into the legs, between the person and the dress, and is delivered with sufficient force to overcome slightly the hydrostatic pressure. Fig. 990 represents the diver in the act of spreading a large bucket of hydraulic concrete upon the bed of a harbor, preparatory to laying blocks for the foundations of a pier. A signal rope communicates with an attendant on a boat, which contains the air-pump. The signals of the diver are communicated verbally by the attendant to a director stationed upon the derrick, by which the buckets of concrete or blocks of béton are moved into position, and by him bells are rung, which enables the attendant at the engine to execute the necessary movements.

DOCKS. A dock is an artificial inclosure in connection with a harbor or river, used for the reception of vessels, and provided with gates for keeping in or shutting out the tide. Docks are divided into two classes: *wet docks*, or basins in which water is shut in and kept at a given level to facilitate the loading and unloading of ships; and *dry docks*, or graving docks, from which the water may be shut or pumped so as to leave a ship dry for inspection or repairs. Dry docks may be again divided into stationary docks and floating docks, of which there are many varieties.

WET DOCKS.—The advantages of these basins are that vessels can be accommodated in the smallest possible space and are enabled to lie constantly afloat; whereas in tidal harbors, where they take the ground through the falling of the tide, they are apt to be strained. When a vessel is in dock she can be easily and at all times moved from place to place, while the operation of discharging and loading can go on regularly during any time of the tide.

*Capacity of Docks.*—The number of vessels that can be accommodated in each acre of a basin is termed its available capacity. A tolerably good approximation to the capacity of a dock is found by the formula $n = \frac{1000}{t} + a$; where $n$ represents the number of vessels per acre, and $t$ their average tonnage, and $a$ is a coefficient which may be taken at from 4 to 5. From this formula the following table has been calculated:

*Table showing Number of Vessels of given Tonnage accommodated per Acre of Dock Area.*

| Tonnage. | No. of Vessels per Acre. | Tonnage. | No. of Vessels per Acre. |
|---|---|---|---|
| 100 | 14.0 | 350 | 6.9 |
| 150 | 10.6 | 400 | 6.5 |
| 200 | 9.0 | 450 | 6.2 |
| 250 | 8.0 | 500 | 6.0 |
| 300 | 7.3 | | |

The capacity of a dock depends not on the area only, but also on the depth. It has been determined that the capacities for tonnage of different channels vary as the cubes of their depths; a law which may be found useful when comparing the relative advantages of two docks, harbors, or navigable tracks. Mr. George Robinson has also shown that by making the Albert Dock at Leith 2 feet deeper than the Victoria Basin, there are 296 tides per year when there will be a depth of 23 feet, whereas at the Victoria there are only 102 tides in the year when that depth occurs. The ratio of the draughts of vessels to their tonnage has been gradually decreasing, but there is not much uniformity in this particular as regards steam-vessels. Under ENGINES, STEAM, MARINE, are tables showing dimensions of many of the ocean steamers leaving the port of New York, from which deductions on the subject can be made. At the Clyde, steam-vessels of from 250 to 400 feet in length draw with their machinery on board from 12 to 18 feet of water, which would give the light draught = loaded draught multiplied by .7, the last quantity being a constant depending on the build. In wooden sailing-vessels the draught is approximately equal to the cube root of the product of the tonnage multiplied by a constant such as the above. This last is assumed as 10 for vessels up to 500 tons, and 7.5 for larger craft. From this is calculated approximately (error on the safe side) the following

*Table showing Size of Vessel that can enter a Dock or Channel of given Depth (Stevenson).*

| FACTOR 10. | | | | FACTOR 7.5. | | | |
|---|---|---|---|---|---|---|---|
| Tonnage. | Draught, Feet. | Tonnage. | Draught, Feet. | Tonnage. | Draught, Feet. | Tonnage. | Draught, Feet. |
| 50 | 7.8 | 250 | 13.5 | 500 | 15.6 | 1,300 | 21.4 |
| 60 | 8.4 | 300 | 14.5 | 600 | 16.5 | 1,400 | 21.9 |
| 70 | 8.8 | 350 | 15.1 | 700 | 17.4 | 1,500 | 22.5 |
| 80 | 9.2 | 400 | 15.8 | 800 | 18.2 | 1,600 | 23.0 |
| 90 | 9.6 | 450 | 16.4 | 900 | 18.9 | 1,700 | 23.4 |
| 100 | 10.0 | | | 1,000 | 19.6 | 1,800 | 23.9 |
| 150 | 11.4 | | | 1,100 | 20.2 | 1,900 | 24.3 |
| 200 | 12.5 | | | 1,200 | 20.8 | 2,000 | 24.9 |

Mr. Thomas Stevenson, in his work on the "Construction of Harbors," whence the foregoing data are extracted, gives a plan for a dock of the form of maximum capacity, semi-octagonal in shape, which has internal jetties with a broken line of quay radiating inward from the angles.

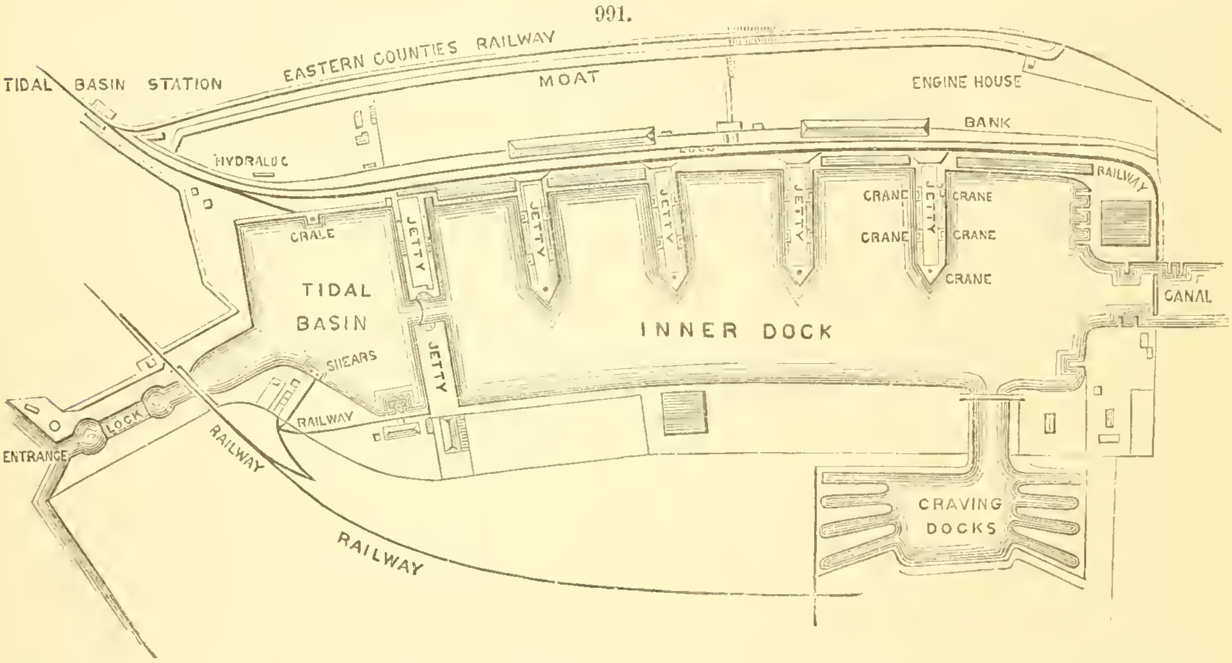
*Quay Proportions.*—The proportions of quays range, according to Sir John Coode, from 200 to 250 feet per acre. Vessels of 150 tons require about 100 feet of quay, and it is desirable to have at least 100 feet of breadth behind the quay.

*Entrances.*—For wet docks, according to Mr. Redman, the entrance should point up stream at an angle of about 60°. The dimensions of locks depend on the class of shipping that has to be provided for. (See *Locks*, under CANALS.) Outer or half-tide basins are formed between the locks and the sea, and are provided with sea-gates, which are kept open until half tide, so as to accommodate additional traffic. In the Liverpool docks the ratio of area of outer basins to area of docks is as 1 to 8.23.

*Construction of Wet Docks.*—Wet docks are constructed with a wall of masonry or of piling, with concrete and tamped-clay filling, and with a clay or concrete bottom. The higher the level of the water in the dock is kept above the low or mean tide of the harbor, the stronger and more impervious the wall requires to be made. When the area is not too great, the water is sometimes maintained at the highest tide-level by pumps, mainly to avoid the necessity of admitting too much sedimentary matter with the entrance of the tide when the water in the harbor is very turbid.

The Victoria Docks, London, Fig. 991, comprise a tidal basin of 16 acres at the entrance from the Thames, and a main dock of 74 acres. The earthy strata which occupied the site of the dock consisted of a top soil one foot deep, a layer of clay about $5\frac{1}{2}$ feet thick, then one of peat from 5 to 12 feet, and beneath this a bed of gravel, lying upon the London clay. The dock and basin were excavated to a depth of 26 feet below high-water mark, and its bottom was puddled with clay to a depth of 2 feet, leaving the finished surface 24 feet below Trinity high-water mark. The entrance

991.




from the river into the basin is by a lock having two pairs of wrought-iron gates, revolving in hollow quoins, the walls of the lock being constructed of cast-iron piling, T-shaped in section, backed with hydraulic concrete. The gates are what are called cylindrical in form; that is, they are portions of a cylinder, with the convexity turned toward the basin. The lock-chamber is 80 feet wide at the bottom and $326\frac{1}{4}$ feet long, including the upper and lower gate-platforms upon which the gates are supported while turning upon a circular-roller path. On the site of the lock the surface of the London clay was 37 feet below high-water mark, and to this depth the excavation was carried at this point, and the foundations of the gate-platforms were laid. Between the platforms the bottom of the lock was filled with clay puddle to a level of 28 feet below high-water mark. The upper gate-platform is $25\frac{1}{2}$ feet below that mark, while the lower one is 28 feet, or at the same depth as the bottom of the lock; so that, the mean fall of tide being 18 feet, there will be 10 feet depth of water in the dock below the upper platform at low tide. The entrance from the tidal basin into the dock is by means of a single pair of gates, similar to those of the lock, placed between two dumb jetties or walls which separate the basin from the dock. The basin and dock are 4,050 feet in length and 1,050 feet in width. There are six jetties—the two just mentioned, which are each 485 feet long, and four others extending from the north wall into the dock a distance of 581 feet, including the pointed terminations. These with the sides of the dock and basin afford nearly 3 miles of quay-room. The four interior jetties are each 140 feet wide for 497 feet, and the surface of the quay varies from 6 to 9 feet above high-water mark. The side-walls are vertical, and constructed of cast-iron piles 7 feet apart from centre to centre, filled in between with brick set in Roman cement, the brickwork being arched toward the back to give strength. Behind the piles and brickwork there is a wall of concrete which was carried up from below the clay bottom, and behind this a filling of clay. The piles are T-shaped in section, and are 35 feet long and 1 foot wide on the face, averaging $1\frac{1}{2}$ inch in thickness, and weighing about $1\frac{3}{4}$ ton each. They are driven to a depth of 28 feet below high-water mark, and therefore 4 feet below the bottom of the dock. The brickwork commences 1 foot above the bottom, and rests upon concrete 3 feet thick. The wall is covered with a cast-iron plate bolted to the heads of the piles, and upon these

lies a timber sill. The piles in the opposite jetty walls are connected by cross-bars, 5 and 17 feet below their heads. Upon each jetty there is a warehouse 500 feet long and 80 feet wide, leaving wharf-room 30 feet wide; and it is also supplied with 9 hydraulic cranes, one of 5 tons power at the pointed end, and 8 others of 3 tons power each along the sides. Connected with the north side is a basin which opens into 8 graving or dry docks.

The West India Docks, constructed in 1802 in a gorge in the Isle of Dogs, comprise an import-dock of 30 acres, an export-dock of 25 acres, communicating with the Thames at Blackwall, and a bonded-timber dock of 19 acres. The gates are 45 feet wide, admitting vessels of 1,200 tons. The whole space occupied by docks and warehouses is 295 acres. The East India Docks, also at Blackwall, completed in 1806, belong to the same company as the former. They include an import-basin of 18, an export-basin of 9, and an entrance-basin of $2\frac{3}{4}$ acres. The gates are 48 feet wide, and the depth of water 23 feet. The Commercial Docks, situated on the opposite side of the river, existed in 1660 under the name of the "Howland Great Wet Dock," and subsequently of the "Greenland Docks," having been prepared for the accommodation of the Greenland whaling-vessels. In 1807 they were greatly enlarged and received their present name; and they are now used chiefly to receive vessels laden with corn, iron, lumber, guano, and other bulky articles. They cover an area of 120 acres, 70 of which are water. The granaries will contain 140,000 quarters of corn. The other principal docks here are the London and the St. Katherine Docks, the latter situated between the former and the Tower. The warehouses in the St. Katherine Docks are built upon the water's edge, without a quay; but this plan has since been disapproved on account of interference with the ships' rigging.

There are numerous other mercantile wet docks in Great Britain, a list of which, including entrance-basins provided with locks, at the principal ports, is appended:

| PORTS. | No. | Area in Acres. |
|---|---|---|
| London | 28 | 350 |
| Liverpool | 38 | 206 |
| Birkenhead | 4 | 142 |
| Bristol | 4 | 79 |
| Hull, exclusively of timber pounds | 7 | $46\frac{1}{2}$ |
| Great Grimsby | 2 | 51 |
| Hartlepool | 1 | 20 |
| West Hartlepool, exclusive of timber pounds | 3 | 32 |
| River Wear | 2 | 41 |
| River Tyne | 4 | 107 |
| Leith | 3 | $15\frac{1}{2}$ |
| Dundee | 4 | 34 |
| Aberdeen | 1 | 35 |

The Atlantic Dock at Brooklyn, Fig. 992, in reality a tidal basin, was constructed by the Atlantic Dock Company, chartered by the State Legislature in 1840. The work was commenced in 1841, and occupied several years. Over 200 acres of land were purchased at a point on the Long Island shore opposite Governor's Island, and 60 acres of the low land and marsh were converted into a basin having 40 acres of water surface. The inclosure on the water-side was made with cribwork piers consisting of timber filled with stone, sunk in trenches 30 feet below high-water mark. The cribs

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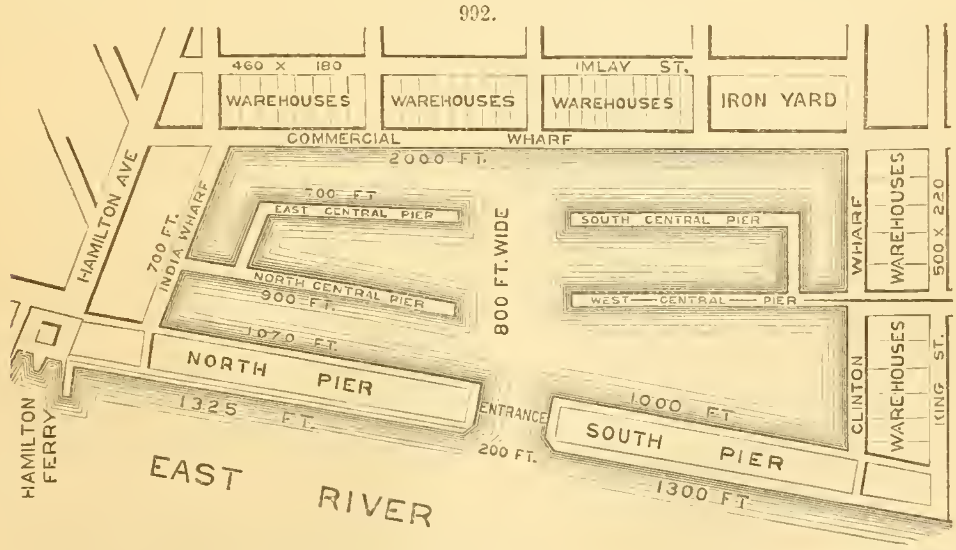


were 25 feet thick at the base, and were placed with their external sides 150 feet apart, that being the width of the pier, the top of which is 10 feet above low-water mark. The space between them was filled with sand and gravel from the excavations in the basin. Piles were driven into the filling to a sufficient depth and sawn off 5 feet below the surface; and upon the heads of the piles the stone foundations of the warehouses were placed. The entrance is between the north and south piers, and is 200 feet wide. The excavation over the whole 40 acres was made principally with dredging machines working by means of an endless chain, and was carried to an average depth of 26 feet below low-water mark, or 25 feet below high-water mark. In the basin, reaching from either

end, are wooden piers of sufficient width for the unloading of ships, built of piles covered with timber and planking. Upon the cribwork piers, one of 1,070 and the other of 1,000 feet in length, there are commodious stone warehouses, 100 feet in depth and extending the length of the piers. Upon the opposite or inland side of the basin is the commercial wharf, 2,000 feet in length, and upon this there are three blocks of warehouses, each 460 feet long and 180 feet deep, besides an iron-yard of the same dimensions.

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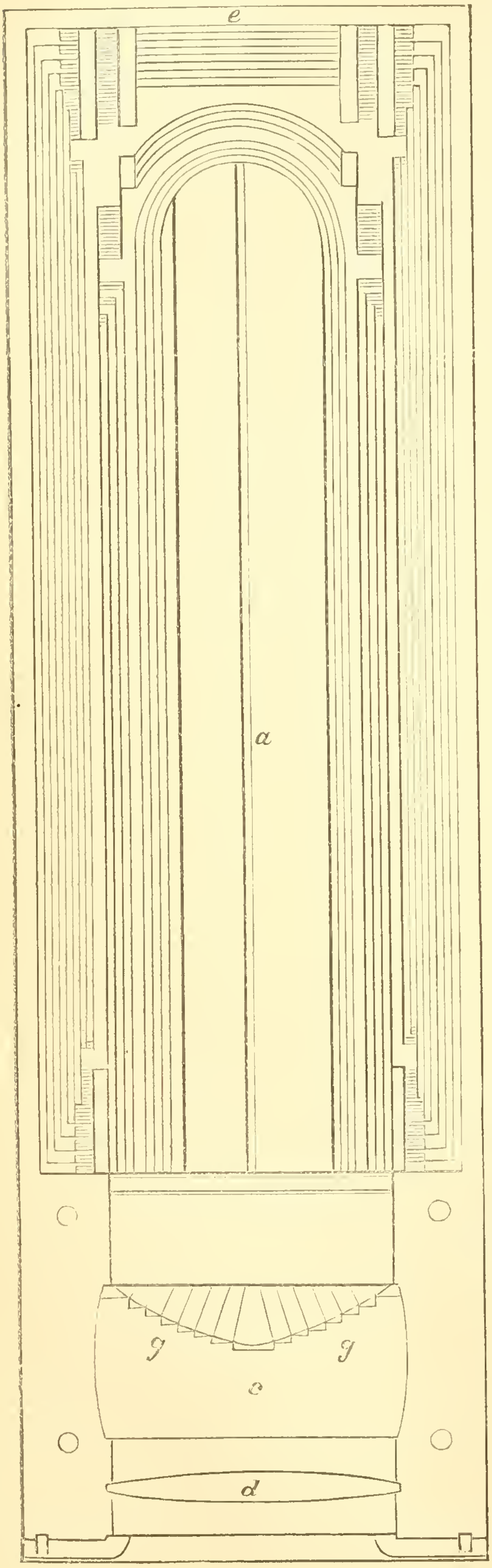


Dry Docks.—I. *Stationary Docks.*—These inclosures, from which, as before stated, the water is pumped out to allow a ship's bottom to be graved or cleaned, are usually built of masonry, but are sometimes constructed of piling, concrete, and clay puddling. Dock-walls should always be made of sufficient strength to resist a pressure of water equal to their height. Minard assigns four-tenths of the height for the thickness, and Rankine takes the ordinary thickness at from one-third to one-half the height. The question of the construction of dock-gates and the strains thereon is one regarding which there is much difference of opinion. For a discussion of the subject the reader is referred to "Minutes of the Proceedings of the Institution of Civil Engineers," vols. xviii. and xix.

*Construction of Dry Docks.*—The dry dock at the Navy Yard, Brooklyn, N. Y., is the largest structure of the kind in the United States. It was commenced in August, 1841, and occupied just 10 years in building. The main chamber of the dock, *a*, Fig. 993, is 286 feet long and 30 feet wide at the bottom, and 307 feet long and 98 feet wide at the top, this being the distance between the folding gates *g g* and the head of the dock *e*. Behind the folding gates is what is called the lock-chamber, *c*, 52 feet long, which length may be added to the dock when it is required, a caisson, *d*, forming the external gate, being sufficient to exclude the water. The bottom is 26 feet below mean high tide, and 30 feet 8 inches below the coping. The foundation had to be constructed in quicksand, and consisted of piling driven to great depth, covered with 18 inches of hydraulic concrete, this covered with cross-timbers of yellow pine 12 inches square, and this again with

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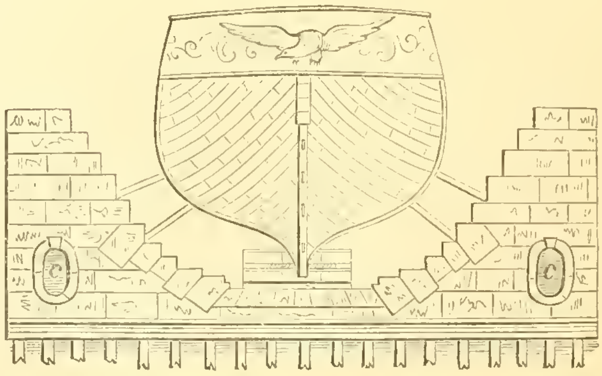


3-foot granite blocks laid in hydraulic cement. A cross-section is represented in Fig. 994. The walls, composed of heavy granite blocks laid in hydraulic cement, are carried up vertically from this foundation, and are 108 feet from outside to outside, being 5 feet thick at the coping and 39 feet at the bottom or lower step, and varying in thickness between these two points in accordance with the curve, which is irregular and made to correspond with the general curve of the side of a ship. The distance between the quoins in

which the folding gates revolve is 66 feet, and this is about the average width of the lock-chamber, and also the length of the deck of the caisson or outer gate, which has also a beam of 16 and a depth of 30 feet. Two culverts, *c c*, one on either side of the entrance and below the surface at low tide, admit water and carry it in a descending course to the bottom of the dock a few feet in front of the inner gates. These culverts have a calibre of 4 feet 9 inches vertical by 2 feet 5 inches horizontal. At the points where they enter the dock commence the discharge culverts, which are carried on either side to a point beyond the head, where they unite and empty into a well under the engine-house. From this well the water is pumped into a culvert which descends to the river and discharges at a point near the entrance of the dock. The pumping-engine can empty the dock in 2h. 10m., its capacity when filled by the tide being about 600,000 cubic feet. When a ship is docked, the filling-culverts are closed, as well as the passages from the dock-chamber to the draining-culverts leading to the pump-well, and the water is pumped from the latter; the ship is then admitted and placed over the keel-block in the centre of the dock; the caisson is next floated to its place, over the recess or groove, and filled with water until it sinks down to the bottom of the masonry fitted to receive its keel; after which the turning gates are closed by men standing on the bridge, and working the four hand-wheels that move the machinery. The culvert-gates in the dock-chamber are next drawn, and the water is allowed to flow into the draining-culvert and well, by which means the water is lowered several inches in the dock in a few minutes, thus hastening the shoring and producing an immediate pressure on the gates, so as to effectually prevent the admission of water and fix them steadily. A complete command of the level at the moment the gates are closed, or when a ship, especially a large one, is about to touch the blocks and requires the placing of shores, is important; and the above method gives a more perfect control of the operation for the first foot than could be obtained by the best regulated pumps and machinery for driving them.

*Table showing Dimensions of Important Dry Docks.*

| LOCALITY. | Length, Feet. | Depth at Mean High Tide, Feet. | Width, Feet. |
|---|---|---|---|
| Brooklyn Navy Yard | 286 | 26 | 30 at floor. |
| Boston (Mass.) Navy Yard | 256 | 25 | 86 |
| Portsmouth, England | 644 | 25 | 80 |
| " " | 644 | 27 | 88 |
| Devonport, " | 437 | 31 | 73 |
| Birkenhead, " | 750 | 29.7 | 85 |
| " " | 750 | 29.7 | 50 |
| Sandon, Liverpool (6 docks) | 540 | .... | 70 to 45 |
| Brest, France (double dock) | 721 | 55 | 92 |
| Somerset Dock, Malta | 428 | 80 | 42.5 |

Floating Docks.—Of these there are several varieties, the chief types of which are noted below.

Rennie's floating dock, Fig. 995, has been constructed after the patent of Mr. G. B. Rennie in the navy yard at Cartagena, and also for the port of Ferrol, Spain. It is 350 feet long, 105 feet wide, and 50 feet high in extreme dimensions. The depth of the pontoon is $12\frac{1}{2}$ feet, leaving a height of $37\frac{1}{2}$ feet from the deck of the pontoon to the deck of the side-walls, so that, if the keel-blocks occupy 5 feet and the deck $4\frac{1}{2}$ feet above water, there will be a clear depth of 28 feet of water for the admission of ships. The total weight of the dock is about 500 tons, and the displacement of the pontoon is equal to 13,000 tons, leaving a lifting power of 8,000 tons. It is constructed of plate, angle, and T iron, riveted together in one structure. The pontoon is divided by a water-tight bulkhead running the whole length, each half being subdivided by 10 transverse bulkheads. There are 4 pumps on each side, of 2 feet 9 inches stroke and 26 inches diameter, worked by steam.

*The Balance Floating Dock.*—This was patented by John S. Gilbert of New York, and consists of a pontoon divided into compartments, which may be so filled with either air or water as to preserve

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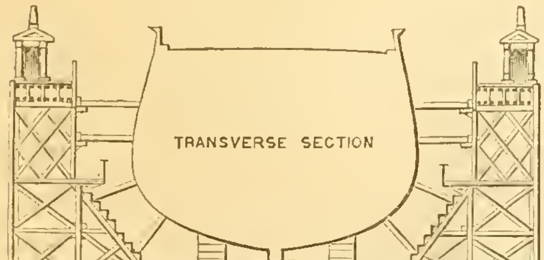


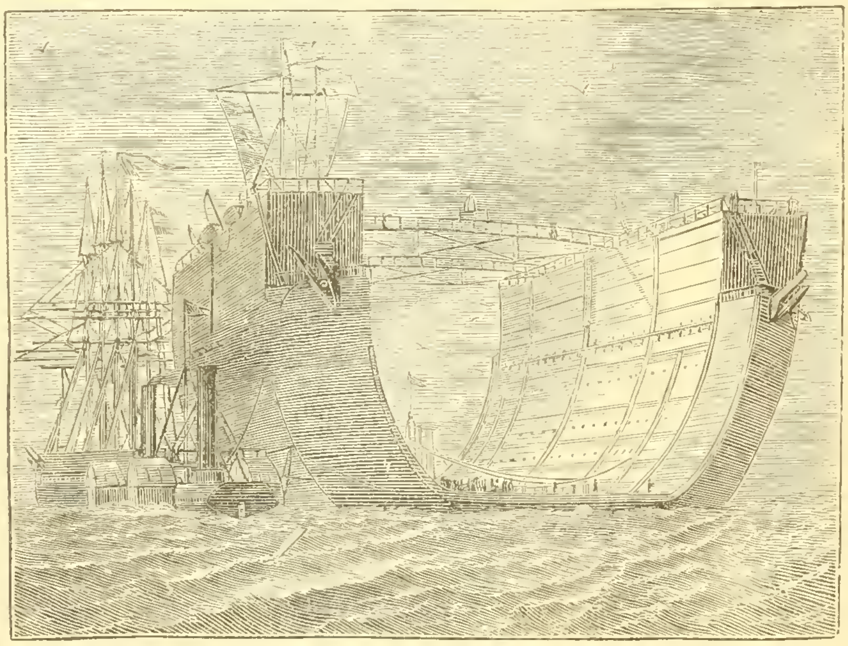

996.

a balance of position, and by its buoyancy to be capable of raising vessels. It may be built of timber and planking, or of wrought-iron and planking. Those which are used in New York have the framework entirely of wood, and one of them has been in use for nearly 40 years. The pontoons may be from 8 to 12 feet in depth, and 100 or more in breadth by 350 or more in length. They are strongly girded and trussed, and have a strong bulkhead running through the middle for the whole length, upon which the keel of the vessel is supported by keel-blocks. At either side the dock rises

into walled chambers, which may be also filled with water or air, and upon the deck of which are placed steam-engines for the purpose of pumping the water from the interior. The ends of the dock are left open, so that when the vessel is raised the water readily flows from the dock. Fig. 996 represents the larger of two docks owned by the New York Balance Dock Company. It is 325 feet long, 100 feet wide, and 30 feet from deck of pontoons to deck of side-walls, or 40 feet in all, the pontoons being 10 feet deep. It has 8 gates on either side for admitting, and 8 others for discharging water, which is pumped out by steam-engines, one upon either wall, of 40 horse-power each. The pumps are 14 in number, 7 on either side, of 36 inches diameter and 35 inches stroke, capable of exhausting with sufficient rapidity to raise a vessel of 3,000 tons in an hour and a half. Its total lifting power is estimated at 8,000 tons. In docking a vessel on the balance dock, the pumps are first set in motion by the steam-engines on the deck above, and, the discharge opening being closed by a gate for that purpose, the water rises in the chamber above the pumps until it is full to the deck of the dock. It is next allowed to flow into the upper chamber of the dock until its weight, acting as ballast, sinks the dock to the required depth. When the ship is floated into the dock, this ballast is drawn off by means of valves, causing the dock to rise by its own specific gravity until it touches the bottom of the ship, after which the vessel is lifted by pumping the water out of the side chambers and bottom tank; and as the dock rises, the water around the ship in the middle chamber ebbs out, so that the quantity of water to be exhausted in raising a vessel is in proportion to her weight and not to her bulk.

*The Bermuda Floating Dock.*—This dock was built in England, and towed to the island of Bermuda by two war-vessels. It cost $1,250,000, and has the following dimensions: Extreme length, 381 feet; width inside, 83 feet 9 inches; width over all, 123 feet 9 inches; depth, 74 feet 5 inches. The weight of the dock is 8,350 tons. As shown in the annexed engraving, Fig. 997, it is U-shaped,

997.

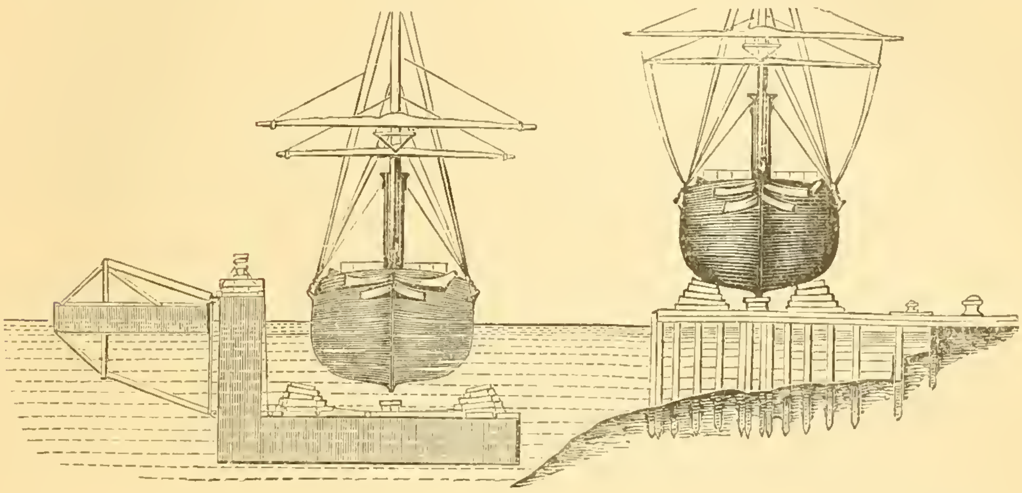


and the section throughout is similar. It is built with two skins, fore and aft, at a distance of 20 feet apart. The space between the skins is divided by a water-tight bulkhead running with the middle line the entire length of the dock, each half being divided into three chambers by similar bulkheads. The three chambers are respectively named "load," "balance," and "air" compartments. The first-named chamber is pumped full in 8 hours when a ship is about to be docked, and the dock is thus sunk beneath the level of the horizontal bulkheads which divide the other two chambers. Water sufficient to sink the structure low enough to admit a vessel entering is forced into the balance-chambers by means of valves in the external skin. The vessel having floated in, the next operation is to place and secure the end caissons, which act as gates, and eject the water from the "load" chamber. Then the dock with the vessel in it rises, the water in the dock being allowed to decrease by opening the sluices in the caissons.

Messrs. Clark, Stanfield & Co.'s floating dock, Figs. 998 A and 998 B, in its general form is composed of a number of pontoons, either of a square or a circular section, which lie parallel to each other at fixed distances apart, and which range transversely to the length of the dock; each of these pontoons is permanently connected at one end to a longitudinal structure which forms the main side of the dock; the pontoons project outward from the side of the dock in the same way as the fingers of the hand, so that the whole structure in plan resembles a comb. The pontoons, when the dock is lowered to receive a vessel, are submerged; but the side of the dock to which the pontoons are attached is never totally submerged, but is of sufficient depth to allow a freeboard of 6 or 7 feet when the pontoons are sunk beneath the bottom of the vessel. When the dock is raised, the tops of the pontoons are well above water, and the side of the dock some feet higher than the deck of the vessel which it supports. Fig. 998 A shows an elevation of the dock submerged, ready to raise a vessel, with the outrigger attached. It will be seen that these elevations resemble the letter L. It is obvious that such a form as this—namely, a dock with only one side to it—would be perfectly

unstable when submerged, but the necessary stability is imparted to it by means of the outrigger arrangement. This outrigger consists of a broad, flat pontoon, divided into numerous compartments, and loaded with concrete ballast until it is half submerged. Its form gives it immense stability. It carries along its middle line a row of rigid upright columns, which project through the

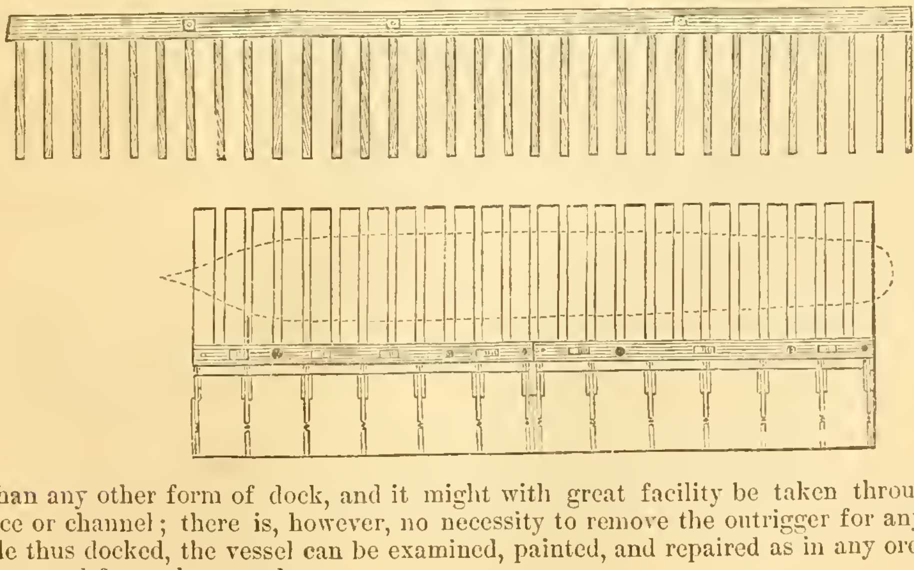
998 A. 998 B.



pontoon some distance above and below, and are stiffened by struts. To the top and bottom of each column is hinged a pair of parallel bars or booms, Fig. 999, which are also hinged at their opposite ends to the sides of the dock, as shown in the diagram, so that the outrigger remains stationary while the dock is free to be raised and lowered vertically, being always retained in a horizontal position by the action of the parallel bars or booms. The movement is, in fact, exactly that of a parallel ruler. Each of the pontoons is usually divided into about 6 separate compartments, by means of 5 transverse vertical bulkheads. The side of the dock to which the pontoons are attached is practically a long box-girder, divided by numerous bulkheads into large water-tight chambers. Its height may vary from 20 to 50 feet, or more; its width from 10 to 15 feet; and its length is about equal to that of the longest vessel intended to be docked. The pontoons are about twice the length of the beam of the vessel to be raised, so as to be available for paddle steamers. Their height may be from 10 to 20 feet, according to the weight of the vessel, and their width from 7 to 15 feet.

In the Russian Nicolaieff dock, the side is 280 feet long, 44 feet 6 inches high, and 12 feet broad. The pontoons are 72 feet long, 18 feet deep, and 15 feet broad, and the clear space between them is 5 feet. The machinery for working the dock is carried in the chambers of the side. It consists of a number of powerful pumps worked by steam-engines in the usual manner. When it is necessary to submerge the dock, the necessary valves are opened, and the water admitted through pipes to the compartments of the pontoons; the dock is thus gradually lowered, its horizontal position being at all times maintained by its connection with the outrigger. The vessel is then floated over the pontoons, water is pumped out until the keel takes its bearing on the blocks, the bilge-blocks are hauled into place by chains in the usual manner, and, the vessel being firmly blocked and shored, the pumping is continued until the vessel is raised to its full height; the valves are then closed. In this position it will be seen that the dock with the ship on it has very great stability quite independently of that afforded by the outrigger; the outrigger, having in fact performed its function—namely, that of controlling the dock when submerged—is no longer of any service, and it might, should occasion demand, be entirely removed. It may be remarked that the dock in this condition is much

999.



narrower than any other form of dock, and it might with great facility be taken through any narrow entrance or channel; there is, however, no necessity to remove the outrigger for any other reason. While thus docked, the vessel can be examined, painted, and repaired as in any ordinary dock, or can be removed from place to place.

The great feature of this system is that this vessel can now be readily lowered on to a fixed staging along the shore, and there deposited high and dry, as shown in Fig. 998 B, leaving the dock free to raise or lower another vessel, or any number of other vessels as required. This staging consists of a series of piles driven into the ground in rows parallel to each other, these rows standing at right angles to the shore. The rows of piles are capped by horizontal timbers, which are exactly the same distance apart from centre to centre as the spaces between the pontoons are, so that, if the width of the pontoons is 10 feet, the clear space between the piles is 12 feet, leaving 2 feet for clearance. The height of the vessel above the water is greater than the height of the staging, so that, when the dock with the vessel on it is brought alongside the staging, the pontoons can enter freely between the rows of piles, and the vessel is carried directly over the staging without touching it. The dock is now slightly lowered by admitting water into the pontoons until the vessel rests upon the keel-blocks on the fixed staging; bilge-blocks are now placed under the bilges, and the vessel being securely shored, the dock is lowered just clear of the vessel, and drawn out from the staging, and is then of course ready to receive other vessels. The lifting of the vessel off the staging and lowering it into the water is simply the reverse of this process.

*The New York Sectional Floating Dock.*—This was patented by Phineas Burgess in 1839. It consists of a number of floating pontoons placed side by side. At the end of each pontoon there is a framework of timber which supports machinery for pumping, being sufficiently high to remain out of water when the dock is submerged. This framework projects beyond the end of the pontoon, and its lower part contains what is called a balance-tank—an air-tight chamber, which may be raised and lowered by means of a rack and pinion connected with the pumping machinery. These tanks have much the same use as the air-chambers in Rennie's dock: by raising them, the depth of the deck of the pontoons is increased; and by lowering them, the pontoons are raised independently of the amount of air or water the latter may contain. Fig. 1000 is a perspective view of one of these docks, the details being exhibited in Fig. 1001. The parts are as follows: *B B*, the balance-tanks; *C*, the keel-block; *D D*, cross-beams supporting the chock-blocks *E*; *E E*, the chock-blocks; *F F*, the outside truss-girders; *f f*, the inside standards of the main framing to guide the balance-tanks *B*; **F*, beam securing the standards; *G G*, the outside standards of ditto; *I I*, the stationary spuds for working the tanks; *J J*, pinions working in the racks on the spuds; *K K*, outline of a vessel on the dock, supported by the side supports *L L*, the chock-blocks *E E*, the keel-blocks *C*, and the balance-tanks *B B*; *L L*, the side supports run up and down by the blocks and tackle *M M*; *O O*, engine-houses on centre section; *c c*, vertical shaft from main shaft in the engine-houses; *g*, the worm working the wheel; *h h*, the worm-wheel working the pinion *J* and spud *I*.

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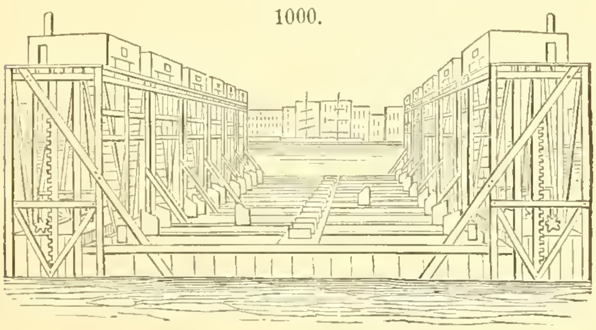


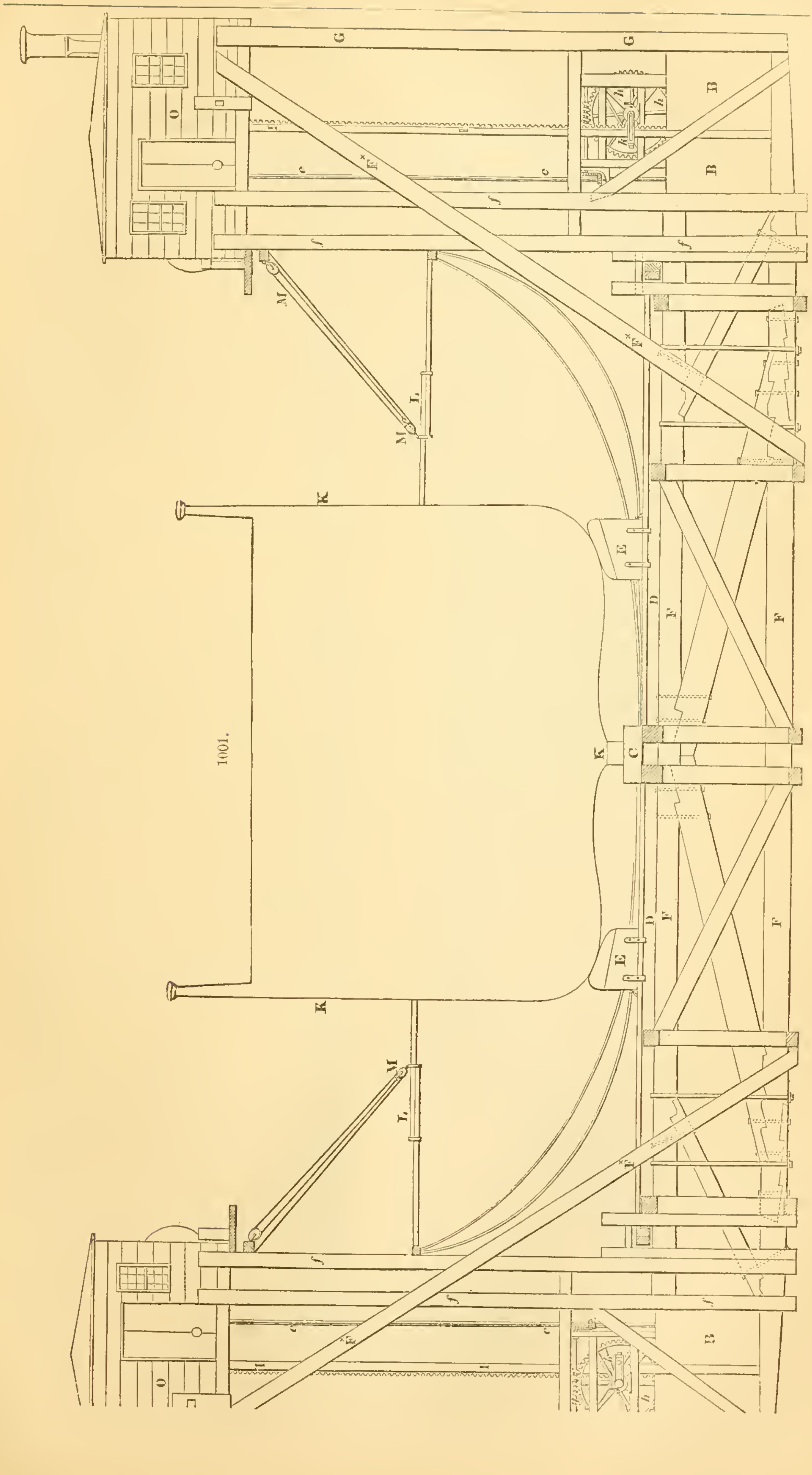
The process of taking a ship into the sectional floating dock is as follows: The dock is sunk to any required depth by opening the gates or valves with which each water-tank is furnished, when the dock necessarily sinks. The dock still being at the required depth, the ship is then introduced between the vertical side-framing, rests on the keel-blocks *C*, and, when supported on the sides by the chock-blocks *E* and side supports *L*, is ready for lifting. The valves which have previously admitted the water into the water-tanks are now closed, the water is pumped out, and the air again fills the tanks, and they rise, bringing with them the vessel to the height necessary for repairs. The vessel is taken out of dock by a repetition of the process of admitting water into the tanks.

A large dock of this description consists of 10 sections, which when placed together form a structure 350 feet long and 110 feet broad. These sections may be placed at some distance apart, so as to increase the length of the dock when required; or if not of sufficient buoyancy, other sections may be added. The advantage claimed for this dock is that the buoyancy of each section may be so regulated as to bear with equal pressure against all parts of the ship's bottom, so that if she has been warped there will be no strain. On the other hand, it is stated that irregularities of pressure caused by swells from steamboats or otherwise more or less reduce this advantage.

*Screw-Docks.*—Among the forms not strictly belonging to either of the two classes of dry docks above described are the screw-dock and the hydraulic screw-dock, which is an improved form of the invention, and with hydrostatic power brought to bear as the lifting force.

The screw-dock in general principle and form is the same as the hydraulic screw-dock. The vessel in the screw-dock is floated on to a timber platform, which platform is suspended from strong mainway pieces of beams on each side, laid on the quay walls, by 8 suspending screws 4½ inches in diameter. The platform is capable of being sunk about 10 feet below the surface of the water, to receive the ship. This platform has several shores on its surface, which are brought to bear equally on the vessel's bottom, to prevent her from canting over on being raised out of the water. About 30 men are employed in working this apparatus, who, by the combined power of the lever, wheel and pinion, and screw, are able in the course of half an hour to raise the platform, laden with a vessel of 200 tons burden, to the surface of the water, where she remains high and dry, suspended between the wooden frames. In a dock of this kind at Baltimore, the platform is suspended by 40 screws of about 5 inches diameter.

*The Hydraulic Screw-Dock* is a slip abutting on the shore, with a suspended keel, allowing the vessel to be raised up vertically, instead of being drawn up on an incline, as in the slip and the marine railway. It consists of two outer and parallel ranges of piling, each bearing a way at the top, from which are suspended chains, to which are slung transverse bearers or swing-beams, over which

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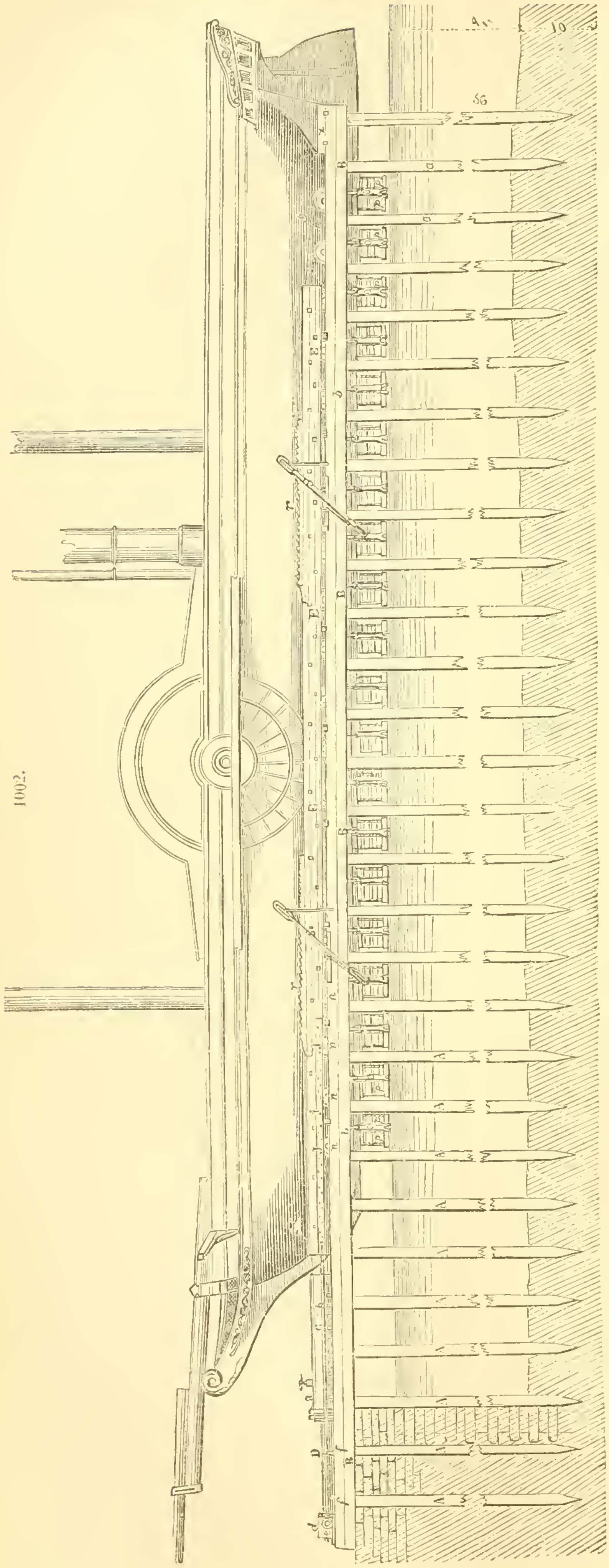


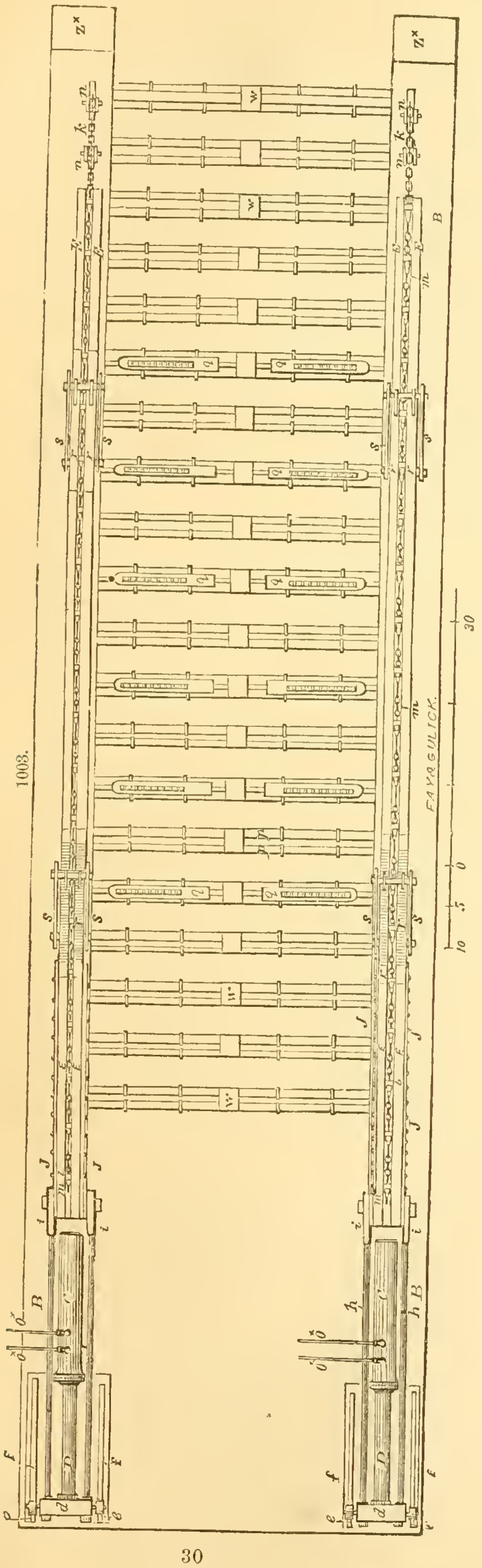
1002.

the vessel to be docked floats; and having arrived over this movable platform or grating, the chains are raised by means of a hydrostatic press, and the vessel brought to the level of the permanent way. The means by which the apparatus is worked are ingenious, and constitute the chief merit of the invention.

The dimensions of the dock are about 165 feet long internally, and 35 feet wide. The distance from the outside of one mainway to the outside of the other is 51 feet. The mainways abut on the land, and run about 38 feet beyond the head of the dock on to the land, resting on a solid quay of masonry, to which they are bolted down, and which supports the machinery.

The mainways *B* are supported on rows of double piles *A*, Fig. 1002, and at their ends are chocks *Z* to hold the vessel in place. On each mainway are side-straps *E*, secured to the cylinder *C*, Fig. 1003, by wrought-iron straps as shown. Along the side-straps are secured bars to which the suspending chain *k*, Fig. 1004, is attached. This head consists of a screw *m*, secured by a nut which regulates the height of each swing-beam so as to fit the keel of the vessel. From the screw the chain *k* descends over sheaves *n*, and thence to transverse bearers or swinging-beams *p*, on which beams are the keel-blocks *a* to support the keel of the vessel. On every second swinging-beam is a traverse-frame *q*, and this supports the chock-blocks against which the sides of the vessel rest. The cylinder *C* contains a ram *D*, to which water-pressure is applied through the medium of powerful engines. The ram is connected to the side rods by parallel rods *h*, as shown in Figs. 1004 and 1006.

The operation of taking a vessel into dock is as follows: The engines are charged with water, and the rams *D* forced out to the full extent of their stroke. By this means the mainstraps *E* are drawn toward the head of the dock, and the cradle of swinging-beams lifted up, so as to allow of the adjustment of the keel-blocks *w w* and chock-blocks *t*, and of the swinging-beams, by means of the adjusting-screws *m*, to the suspending chains. The cylinders are then discharged, the rams fleeted back, the pawls loosed, and the cradle of swinging-beams sunk again by its own weight, the main-



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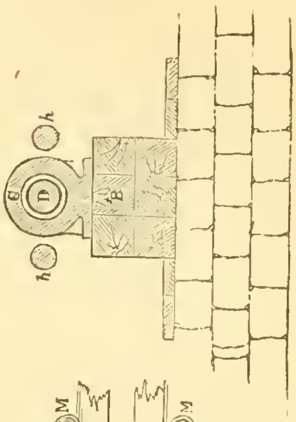

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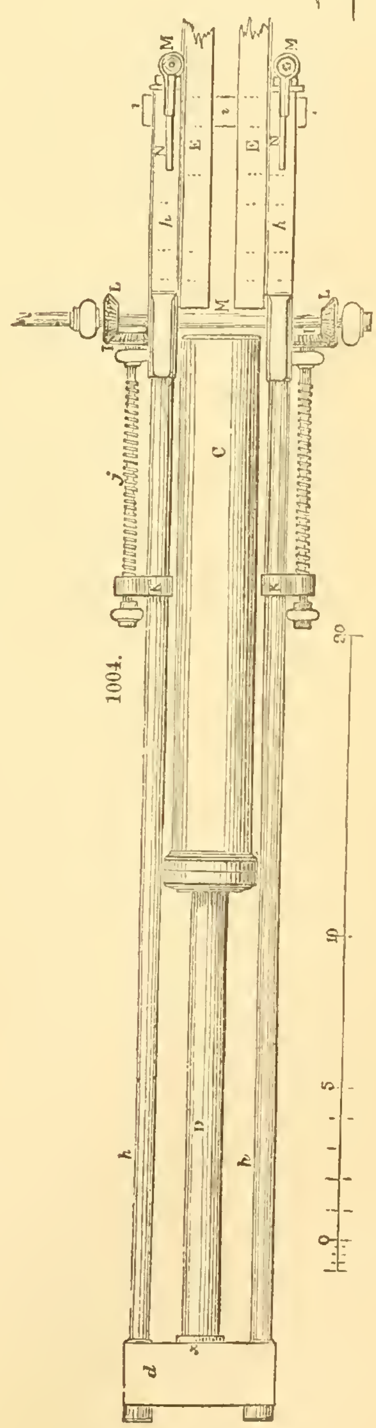

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straps being checked from running over the mainways by the chocks $Z^*$. It will be observed that the cradle may be stopped at any required depth by closing the escape-valves, and by lowering the pawl-bars *s* on the ratchet-frames *r*. The vessel to be repaired is then floated into the dock, brought over the keel-blocks, and the hydrostatic engines and pumps set to work until sufficient pressure is created to raise the swing-beams up to the keel. The motion is then stopped, and the traverse-frames *q* and chock-blocks *t* hauled in by the tackle toward the centre of the cradle, so as to take a uniform bearing under the body of the vessel. When they have done so, the pawls *x* are let fall on the rack so as to fix them in their places. The vessel is now shored up and the engines again started, when by the hydrostatic pressure the rams are forced in a few minutes out of the cylinders, dragging the mainstraps *E*, which take the chains along with them, and the vessel is raised on the cradle of swing-beams, as represented in Fig. 1002, high and dry above water, so as to allow of the inspection by the shipwrights of every part of her bottom. The cradle is supported on the platform by the pawls and racks *s r*.

*Works for Reference.*—Elmes, T., "Docks and Port of London and Liverpool," 1838; "Life of T. Telford," with folio atlas of plates, 1838; Sganzin, "Cours de Construction," 3 vols. and atlas, Paris, 1839–'41; Minard, "Cours de Construction des Ouvrages Hydrauliques des Ports de Mer," 2 vols., Paris, 1841; Webster, T., "The Port and Docks of Birkenhead," London, 1848; C. B. Stuart, "The Naval Dry Docks of the United States," New York, 1852; Sir J. Rennie, "Theory, Formation, and Construction of British and Foreign Harbors," 2 vols., 1854; Garsend et Labour, "Travaux Hydrauliques Maritimes," Marseilles, 1861; Vuigner, "Entrepôts de La Villette," Paris, 1861; Roffiaen, "Constructions Hydrauliques," 3 vols., Brussels, 1861–'63; Humbers, "Record of Modern Engineering" for 1864–'66; "Encyclopædia Britannica," 9th edition, article "Harbors." See, also, numerous papers on docks in the *Minutes of the Institution of Civil Engineers*, *Annales des Ponts et Chausées*, *Annales du Génie Civil*, *Engineer*, and *Engineering*.

DOG. See Lathe-Dog.

DOOR. See Carpentry.

DRAINAGE. In order that a district may be in a perfect state as regards drainage, the water-level in the branch drains, which directly receive the discharge of the field drains, should be at least 3 feet below the level of the ground at all times. When it rises above that level the ground becomes awash or flooded, according as the water-level is below or above its surface. Each water-channel must have sufficient area and declivity, when at its fullest flow, to discharge all the water that it receives as fast as such water flows in, without its water-level rising so high as to obstruct the flow of the branches it receives, or to lay land awash. The questions likely to present themselves to an engineer, as to the causes of defective drainage and the means of improving it, are: 1. Whether, and to what extent, it is practicable to diminish or prevent floods by the construction of store reservoirs. 2. Whether the channels of the streams contain removable obstructions, such as shelves of rocks or other shallows, narrow places, islands, ill-designed weirs and bridges; and how such obstructions are to be removed, or the last rebuilt. 3. Whether the channels are defective and liable to be obstructed through the instability of their beds, and how such instability is to be prevented. 4. In the case of a smaller stream having too little declivity, which falls into a larger stream, whether that declivity can be increased by diverting the course of the smaller stream, so as to remove its outfall to a lower part of the larger stream. 5. Whether the course of a stream, being too circuitous, can be improved by a diversion; and whether, in the event of improvements being required in the channel of a stream, it is best to execute them in the existing channel, independently of the question of circuitousness. 6. Whether the branch drains are of sufficient discharging capacity. 7. To what extent the water-channels are capable of acting as temporary reservoirs for moderating the rapidity with which flood-waters descend from them into lower and larger channels. 8. To what extent the lands adjoining a river, which are liable to inundation, act in the capacity of a reservoir, and what will be the effect upon the part of a river below them of preventing or diminishing such action. 9. Whether the drainage can be sufficiently improved by improvements on the water-channels alone, or whether, on the other hand, it is advisable to use embankments for the confinement of floods within certain limits.

*Discharging Capacity of Branch Drains.*—The branch drains in country drainage should be made capable of discharging at a uniform rate the greatest available rainfall known to take place in a period whose length is greater according as the soil is more retentive. It is probable that, in most cases of cultivated land, 24 hours will be found a sufficiently short period; that is, each drain which directly receives water from the fields should be capable of discharging in 24 hours the greatest available rainfall of 24 hours; for steep and rocky ground the period must be shortened, probably to 4 hours; but the best method in each case is to ascertain the period by an experimental comparison of the rainfall with the discharge of drains.

*Action of Channels and Flooded Lands as Reservoirs.*—The volume of space contained between the ordinary water-surface of a given portion of a stream and the flood-water surface, whether such space be wholly contained between the banks of that portion of the stream, or partly between such banks and partly over adjoining lands liable to inundation, constitutes a reservoir for retaining the *excess of the total supply of water during a period of flood rainfall from the district drained by that portion of the stream, above the greatest quantity that the stream is capable of discharging in the same period*, until the flood rainfall is over, when that excess flows away by degrees. The existence of that reservoir room thus renders efficient a water-channel of less discharging capacity than would otherwise be necessary; and if such reservoir room is diminished, either by improving the channel so as to lower the flood-water surface, or by contracting the space by means of embankments, care should be taken that the discharging capacity of the channel *below* the district in question is increased to a corresponding extent; otherwise the effect of diminishing the extent of floods in that district may be to increase it further down the river.

*Embankments.*—When the land adjoining the stream cannot be sufficiently guarded from inundation by improvements in the channel, embankments may be erected. Where a main embankment extends for a long distance, uninterrupted by a tributary stream, the land protected by it is often divided into portions by means of embankments called "land-arms," diverging from the main embankment, the object of which is that, in event of a breach being made in the main embankment, the inundation may be confined to a limited extent of ground. Behind and parallel to each main embankment there runs a "back drain," the material dug from which, if suitable, may be used for making the embankment. The back drain serves as a reservoir to collect the drainage of the land protected by the embankment when the river is in a state of flood, and its dimensions are to be regulated accordingly. The waters of the back drain are discharged into the river (when its surface is low enough) through a series of pipes traversing the embankment, and having flap-valves opening outward to prevent the return of water from the river. An efficient form of these valves is an iron grating or perforated plate covered with a flap of vulcanized India-rubber. The embankments should be made of clay, rammed in layers 1 foot deep, or thereabouts. When of moderate height, and not exposed to great pressure, they may have slopes of 1½ to 1 or 2 to 1.

*Tidal Drainage* is the drainage of lands which are above the low-water mark of ordinary tides, and either below high-water mark, or so near that level that their drainage waters can only be discharged in certain states of the tide. Such lands are defended against inundation of the sea by means of embankments. The best mode of draining a district of this sort is a canal extending completely through it, which acts alternately as a reservoir and as a channel. The *top-water level* of the canal is to be fixed so as to give sufficient declivity to the branch drains. Its *low-water level* will be above that of low water of neap tides, to the extent of one-fifteenth part of the rise of such tides. The space contained in the canal between these levels is the *reservoir room ;* and, inasmuch as the length and depth of that space are fixed, the breadth midway between these levels is to be made sufficient to give reservoir room for the greatest quantity of drainage water that ever collects during one tide. The depth of the canal must be made at least sufficient to enable the whole of that quantity of water to be discharged in the interval between one hour before and one hour after low water, the mean velocity of outflow being assumed to be about equal to that due to a declivity of the height between high and low water levels in the whole length of the canal, and to its hydraulic mean depth when full up to its middle-water level. The outer end of the canal is to have large flood-gates capable of throwing its whole width and depth open at once.*

*Drainage by Pumping* (see PUMPS) is extensively employed in lands below high-water mark. The largest pumping machines ever built are employed in the reclamation of the Ferrara marshes, northern Italy. The tract to be reclaimed covers an area of 200 square miles, and the work which the pumps have to perform is to raise rather over 2,000 tons of water per minute a mean lift of 7 feet 3 inches, the maximum lift being 12 feet. The water thus raised is delivered into the river Volano, at Codigoro, where the machinery is situated. The plant provided to perform this work consists of 8 centrifugal pumps disposed in pairs, each pair being driven by a pair of compound engines situated between them. When working at the mean lift of 7 feet 3 inches, each of the 8 pumps is constructed to discharge 57,000 gallons per minute, the aggregate discharge from the 8 pumps when working at this lift being consequently 456,000 or nearly half a million gallons per minute, equal to 656,640,000 gallons per day of 24 hours. The capacity of the present Croton Aqueduct at New York is 110,000,000 gallons per day. The Ferrara pumping machinery, therefore, discharges 6 times the quantity of the Croton Aqueduct. Again, 456,000 gallons, or 72,960 cubic feet per minute, would supply a stream over 103 feet wide and 4 feet deep, running at a speed of 2 miles per hour, or 176 feet per minute; while the delivery for a single day would also suffice to fill a reservoir a mile square to a depth of about 3 feet 9 inches.

*Drainage of the Zuyder Zee.*—Extensive as are the Ferrara reclamation works, a still more extensive scheme is about to be carried out (1878)—namely, the draining of a portion of the Zuyder Zee, having an area of 485,775 acres, or about 759 square miles. The tract thus reclaimed will add nearly 6 per cent. to the area of Holland. To inclose the tract to be reclaimed, a dike 25 miles long, 164 feet wide at its base, and rising 26 feet above the water-line, will be made, the dam starting at Enkhuisen and running in an easterly direction to the island of Urk, thence proceeding southeast to the island of Schockland. From the latter island it will be continued to the mainland, which it will join at Kampen, just above the mouth of the Yssel. The area thus inclosed will be divided into squares, which will be successively pumped dry by suitable machinery.

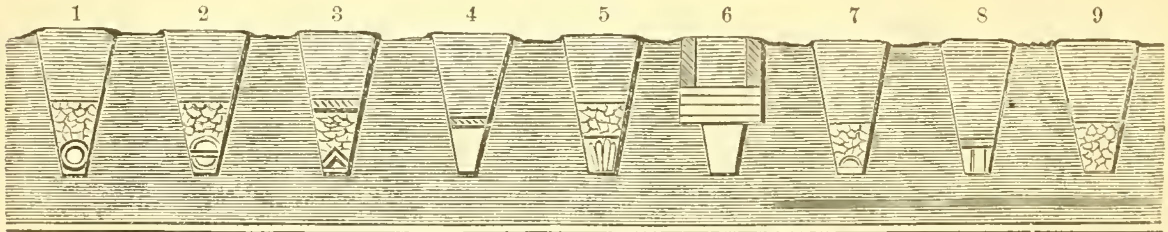
*The Drainage System of Holland.*—Along much of the seaboard of Holland the waters of the ocean are kept from overflowing the land by immense dikes. The country is divided into several districts called hydraulic administrations, each of which has three divisions of surface—viz., natural lands, basins, and polders. The basins comprise the marshes, lakes, canals, and drains having one surface level, which is below high and above low tide, and connect with the sea by sluices furnished with gates, which open when the internal waters are higher than the external, and shut when they are lower. The polders are lands which lie below the surface of the waters in the basins, and can only be kept dry by pumping. The Rynland hydraulic administration comprises 305,000 acres, which, before the draining of Haarlem Lake (completed in 1852), was divided into 76,000 acres of natural lands, 56,000 acres of basin, and 173,000 acres of polder lands; but since the addition of the lake to the latter, the basin only covers 11,500 acres, while the polder lands have an area of 217,500 acres. The basins, however, are the reservoirs of the waters which are raised from the polders, and also of the drainage from the natural lands. When the tides are regular, at every ebb they empty a portion of their contents, and thus maintain a capacity to receive the natural and artificial drainage until the next ebb; but if by the action of the winds the external waters are held at

* The foregoing is mainly abridged from Rankine's "Civil Engineering."

a higher level than those in the basins through the period of an ebb tide, a collection of water in the latter ensues, and may come to equal their capacity. Before this occurs, however, the pumping from the polders must cease, for some space must be allowed for the natural drainage. At about the mean level of the tides in the Zuyder Zee there is a mark upon a pile, which is called the A. P., or Amsterdam pile, and which is the point of reference for regulating the height of water in the basins. There is also a mark for each administration, called the point of arrest. This point is not at the same level for all the administrations, some being allowed to continue their pumping operations longer than others. If the water in the basins were allowed to become too high, there would be danger of the overflowing and breaking away of the dikes. It will, therefore, be seen that the area of the basins is an important matter. If it bears only a small proportion to that of the land to be drained, they soon become filled; and unless they can empty their contents into the sea, the drainage of the polders must cease, and consequently they will become overflowed. As the range of tide along the Dutch coast is about 6 feet, only a small range of rise and fall, or capacity, can be allowed for the basins when the area bears so small a proportion to that of the drained land as it does in the Rynland hydraulic administration, since the drainage of Haarlem Lake has so greatly reduced the basin area. One circumstance has been taken advantage of in the work of drainage, which is that the southwest winds raise the level of the waters in the northeast portion of the basins, so that they may continue to discharge their contents longer than they could if they remained level. The southwest end of the Zuyder Zee, also, by having its water-level depressed, can continue to receive the drainage from the lands longer than if the surface remained level. The wind, therefore, is utilized as a source of work or energy, which goes far to make up the loss incurred by diminution of the area of the basins. The drainage of Haarlem Lake had become a matter of necessity more than of utility; for, as it lies in a peat formation of great depth, connected with other lakes, the barriers were constantly being washed away, which, by increasing the surface of the water, allowed the waves to become higher by the action of the wind, and thus the surrounding country became subject to inundation. This work, undertaken in 1839, was a gigantic operation. From an area of 70 square miles of average depth of water of $12\frac{3}{4}$ feet, situated below the level of any sluices that could be construeted, it was required to raise the water an average height of 16 feet, and to an estimated possible amount of 35,000,000 tons in a month. An enormous steam-engine was constructed in London for working 11 pumps of 63 inches diameter each and 10 feet stroke, the maximum capacity of which was to raise 112 tons of water 10 feet at each stroke. These were set around the circular tower which contained the engine, and from the upper portion of which the balance-beams radiated, one for each pump. They raised in actual work 66 tons per stroke, discharging the water in a large canal 38 miles long and from 115 to 130 feet wide. Two other similar engines were applied to the same work, and the pumping was continued from May, 1848, to July 1, 1852. Then the area was thoroughly drained. The entire expenses from the commencement of operations in 1839 to the close of 1855 were estimated at £748,445, which would be more than paid by the proceeds of the sale of the lands.

*Drain-Conduits.*—Covered drains are made in a variety of ways, as shown in Fig. 1007, in which 1 is a perforated drain-pipe of circular or oval section, covered in by stones or earth; 2 consists of two

1007.




semi-cylindrical tiles respectively above and below a flat tile, the whole covered in by stones or earth; 3 consists of a bed stone and side stones, to form a triangular duct, covered in by stones, a layer of turf, and the filling of soil; 4 shows a drain for tenacious soils, where a shoulder is made to support the flat stones which bear the superincumbent earth; 5, assorted large stones at the bottom, covered in by smaller stones and a filling of soil; 6, drain for peaty soils, which may be covered in with blocks of the peat or by turfs, which will preserve their position for a considerable time if laid properly; 7, a duct formed with a flat tile and an arched semi-cylindrical tile, covered in with stones to allow percolation of water, and closed with soil; 8, where a flat stone is obtainable, two side stones and a cap covered in with soil; 9, a layer of stones in the bed, covered by the earth which had been removed in digging.

*Drainage of Land by Pipes (Haswell).*

| SOILS. | Depth of Pipes in Feet and Inches. | Distance apart in Feet. |
|---|---|---|
| Coarse gravel sand | 4 6 | 60 |
| Light sand with gravel | 4 | 50 |
| Light loam | 3 6 | 33 |
| Loam with clay | 3 2 | 21 |
| Loam with gravel | 3 3 | 27 |
| Sandy loam | 3 9 | 40 |
| Soft clay | 2 9 | 21 |
| Stiff clay | 2 6 | 15 |

Earthenware pipes are of various qualities as to texture, from a porous material like that of red bricks, to a hard and compact material which is glazed to make it water-tight. They are made of various diameters, from 2 inches to nearly 3 feet, and in lengths of from 1 foot to 3 feet. Their chief use is as small covered conduits. The joints are most commonly of the spigot and faucet form, being made tight with cement or with a bituminous mastic.

Sewers are systems of conduits in towns for removing impure water. The gutters or channels run along each side of the carriageway, and are usually about 3 inches deep. They collect the surface-water from the road, and discharge it into the side drains through transverse tubes, which pass below the fences and footway. Mitre-drains are small underground tile-drains, or tubes diverging obliquely from the centre line of the roadway at intervals of 60 yards or thereabouts, and leading with a declivity of about 1 in 100 into side drains. In towns the channels discharge their water into the sewer through passages called gully-holes, sometimes having horizontal openings covered by gratings, sometimes vertical openings in the curb of the footway. In order to prevent the escape of foul air through them, they are provided with siphon-traps or with valves opening inward.

The first point to be attended to in laying out main sewers is, that they shall be straight from point to point. There is no reason that they should follow exactly the middle of the streets where they are not straight, but they should be made straight from one point to the next. The curves should be gentle. The junctions should be, as in the case of the main water-pipes, curved. Rankine says that main sewers should not be less than 2 feet broad, and that the velocity in them should not be less than 1 foot in a second, for fear of choking up, nor greater than 4½ feet in a second, because with a greater velocity than this there is too much scouring. The usual plan, then, is to make sewers which are capable to a certain extent of acting as drains also. That end is often realized by setting the bricks of the invert, as it is termed, in cement, and setting the others with mortar. The bricks of sewers ought always to be set in hydraulic mortar or in cement.

In main sewers the incline should be about 1 in 600, and a greater incline in the smaller sewers, and the greatest incline in the house-sewers. The incline of the pipe-sewers that come from the houses should not be less than 1 in 60. Where sewers are joined the incline should be greater. Where a small sewer enters into a large one there should be a quicker incline for some little distance. A larger sewer should never open into a smaller one; neither should a sewer open into one of the same size, but always a smaller one into a larger one. The inverts should not be level. The invert of a smaller one should be higher up than that of the larger one, so that there may be a fall. "Main sewers and drains should be adapted," as Mr. Rawlinson says, "to the town area, length of streets, number of houses, surface area of house yards and roofs, number of street-gullies, and volume of water-supply."

The best shape for sewers has been decided to be the egg-shaped section. The following proportions are given by Haswell: Width at bottom = one-third of height; height = radius of side; width at top = two-thirds height. The following table, from the same source, shows the dimensions, areas, and volume of work per lineal foot of egg-shaped sewers of different dimensions:

| INTERNAL DIMENSIONS. | | | | VOLUME OF BRICKWORK. | | |
|---|---|---|---|---|---|---|
| DEPTH. | Diameter of Top Arch. | Diameter of Invert. | Area. | 4½ Inches Thick. | 9 Inches Thick. | 13½ Inches Thick. |
| Feet. | Feet. | Feet. | Square Feet. | Cubic Feet. | Cubic Feet. | Cubic Feet. |
| 2¼ | 1.5 | .75 | 2.53 | 2.81 | ..... | ..... |
| 3 | 2.0 | 1.00 | 4.5 | 3.56 | ..... | ..... |
| 3¾ | 2.5 | 1.25 | 7.03 | 4.31 | 9.56 | ..... |
| 4½ | 3.0 | 1.5 | 10.12 | 5.06 | 10.87 | ..... |
| 5½ | 3.5 | 1.75 | 13.78 | 5.81 | 12.75 | ..... |
| 6 | 4.0 | 2.00 | 18.00 | 6.56 | 14.25 | ..... |
| 6¾ | 4.5 | 2.25 | 22.78 | 7.31 | 15.75 | 24.75 |
| 7½ | 5.0 | 2.5 | 28.12 | .... | 17.06 | 27.00 |
| 8¼ | 5.5 | 2.75 | 34.03 | .... | 18.00 | 28.41 |
| 9 | 6.0 | 3.00 | 40.5 | .... | 19.69 | 30.94 |

It has been determined that earthenware pipes cannot be advantageously used if over 12, 15, or at most 18 inches in diameter. Above this last limit it is cheaper to build a brick sewer.

The most approved method of ventilating sewers is to have plenty of openings into and above the main sewer, and to have special ventilating openings connected with the man-holes along each sewer at certain intervals, in the middle of the streets. Cleansing of sewers is performed usually by flushing. This is effected either by stopping the sewage at certain places and so giving it a higher head, which is the plan often adopted, or by having some special reservoirs of water (collected for the purpose) at the higher parts of the sewers which can be allowed to rush down them; or again, by making arrangements for the supply of a sufficient amount of water to flush them continually. And they should be flushed regularly, or deposit is sure to occur.

In Paris, the sewers run along the bottom of subways under the streets. In order to flush the pipes, a wagon which runs on rails on each side of the subway beside the sewer has a flap which descends from the wagon into the sewage below. The force of the sewage pushes this flap on, and moves the wagon with it, when the flap displaces everything before it.

*Pneumatic Sewerage.*—The most successful system of pneumatic sewerage is that devised by Captain Liernur, which is in use in many towns in Holland. The project is outlined as follows:

"In a building, in any convenient part of the town, is placed a steam-engine, which drives an air-pump, so as to maintain about three-fourths vacuum in certain cast-iron hermetically-closed reservoirs sunk below the floor. From these reservoirs central pipes radiate in all directions, following the

main streets. On these central pipes are laid, from distance to distance, street reservoirs sunk below the pavement. From the street reservoirs, up and down the street, are main pipes, communicating by short branch pipes with the closets of each house. All the junctions of pipes with reservoirs are furnished with cocks, so that they can be shut off or turned on at pleasure, like water-mains, and are got at by cock-boxes, and turned by keys in the ordinary way. The vacuum created in the central building reservoirs can thus be communicated to any given street reservoir, so as to furnish the motive-power by which, when the connections with the houses are opened, all the closets are simultaneously emptied. When their contents reach the central reservoir, they are in like manner forced through the central tubes to the reservoirs under the central building, and thence transferred by means of vacuum-power to hermetically-closed tanks above the floor of the building. From these retorts the matter is decanted in a fluid form in barrels, for immediate transport to the country, by means of hermetically-closed apparatus."

With this system there must also be sewers for rain-water, street-drainage, slops, etc., and separate pipes for drainage of the soil.

*House-Drainage.**—The prime object of house-drainage is the removal of the refuse with all possible speed. Every device by which any part of it is hoarded or retarded in or about the premises is to be carefully avoided.

To secure a prompt and continuous flow, drains must be smooth inside, must be well laid, of a proper size, and have sufficient slope to render them self-cleansing. Where the last is not practicable, there should be provision for frequent flushing. They should also be as nearly impervious as possible, to avoid contaminating the surrounding soil. For house-drains, no material is so good as cast-iron, with calked lead joints. But glazed stoneware pipes, carefully put together with hydraulic cement, will make very good drains outside the house walls, if the soil is firm and not liable to settle. Their connections or branches should never be at right angles, but oblique, so that T-joints (Fig. 1008) or branches should never be used; they always tend to produce an accumulation of solid matter. Y-joints or branches (Fig. 1009) can always be obtained, and the position of the drain can generally be adapted to their use by taking a little pains. When being laid, a swab should always be drawn through them, to wipe the surplus cement from the joint on the inside, every new piece put into the trench being strung on to the line or rattan which carries the swab, and draws it along.

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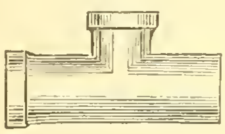

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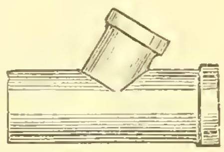

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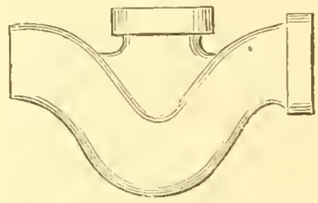

A frequent mistake is made in laying too large-sized pipes for drains, arising from the notion that small pipes are more likely to be choked. The fact is, that all increase of size above the requirements of capacity is an actual injury, by diminishing the scouring power of the current; so that, if laid with a fall of 2 feet or more in 100 feet of length, a 4-inch pipe is better than a larger one for a house-drain used by some 50 persons, because, with this limited flow, the small one would scour better than the larger one. If rain-water is admitted from the roof-gutters, either for convenience or flushing, a larger size is perhaps needed; but 6 inches is ample, even then, for any ordinary house-roof. If the fall is less than 2 per 100, flushing may be needed. Latham says that, in order to be self-cleansing, the house-drain should convey its contents at the rate of 3 feet per second. To attain this velocity, a 4-inch drain must have a fall of about 1 in 100, and a 6-inch drain must have a fall of about 1 in 140, even when half full. As such drains seldom run half full, they cannot be relied upon as self-cleansing, unless laid with nearly double the above rate of slope—say 2 per 100 for 4-inch drains, or $1\frac{1}{2}$ per 100 for 6-inch drains. For hotels and large establishments containing many receptacles for sewage and many branch drains, a 6-inch pipe would be ample, unless rain-water be admitted from extensive roof-surfaces. In this case, the size of the drain is governed, first, by its rate of fall, which is generally limited by local topography; and second, by the size of the roof to be drained. In our climate, a rainfall of at least $1\frac{1}{2}$ inch per hour from the roof-surface should be provided for, adjusting the size of the drain to carry this rainfall. In such cases the sewage can be practically ignored, for its volume is quite insignificant in comparison with that of the rain-water. The problem then becomes a question of hydraulics, and reference must be had to the governing elements and well-known physical laws, thence computing the required size.

In all houses draining into sewers, the place where a trap is most essential is outside of the house-walls, on the main house-drain, after it has collected all the branches which are tributary to it, and between this point and the sewer.

Owing to the rigor of our northern winters, all out-of-door drains are here of necessity kept deep in the ground. The best sort of disconnection we can apply is to introduce a pipe-trap between the house and the sewer. This should not be a built chamber with square corners, which might collect solid matter, but a mere depression in the pipe itself, having the same sectional area as the pipe, and therefore containing the minimum of matter for decomposition. (See Fig. 1010.) Such traps may sometimes be forced by the compression of air in the street sewers, especially if these are tide-locked at high water. To provide against this, a vent-pipe, of 4 inches diameter at least, should in cities be led from the hole in the trap directly up the side of the house, like a water-

* Abridged from the "Seventh Annual Report of the State Board of Health of Massachusetts," 1876.

conductor, and above all dormer windows. The water-conductor itself will not answer for this purpose, for the compression of air in the sewer is most likely to occur during a heavy rain, when the water-spouts are fully occupied as such, and are therefore incapable of giving vent to the gas, for which special outlet must be given. In suburban districts, a vent into a pile of loose stones, or a man-hole chamber under ground, will answer. (See Fig. 1011.) During the winter this chamber may be filled with dry leaves, etc., and the vent covered with wire netting, in order to prevent freezing.

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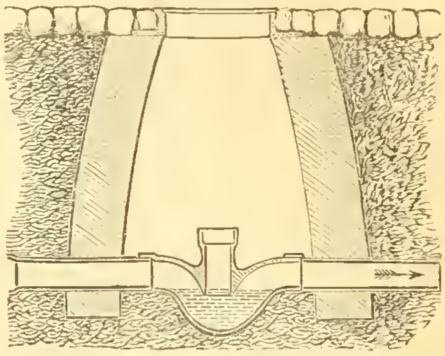

The remedy for the settling and breaking of house-drains, when laid on filled land, is by no means simple. Wooden boxes are slightly pliable, and, if made with care and well clamped, may answer sometimes for temporary house-drains, till the material under the street has ceased settling; but even wooden boxes cannot be bent far without opening joints and becoming leaky. If houses must be built and occupied in such places, the only sure way of constructing a permanently tight house-drain would be to drive a row of piles for its foundation between the house and the sewer. Even then, if the sewer is not built upon piles—and they rarely are—the break would occur where the piles cease, for nothing else is rigid over the compressible mud of these regions. The use of cast-iron drain-pipe all the way to the sewer, with calked lead joints, is recommended by some authorities, in soils subject to settling. But even iron pipes will break, if rigidly connected, about as soon as stoneware, though, having fewer joints, they may break in fewer places. They are certainly no sure remedy for this evil. If a tight flexible pipe could be made, it might answer the purpose for a while; but such a thing is yet to be invented in a permanent form.

*Drains within the House-Walls.*—The above remarks apply chiefly to the drains outside of houses. But that portion of the drain which is *within* the walls deserves still more rigid scrutiny.

In planning house-drains, they should be got outside the walls of the house as directly as possible. In public institutions, or other large buildings, where a large number of receptacles of sewage is provided, the main drain for the collection of the whole should be outside the walls wherever practicable, for the reason that fewer joints of pipe, and fewer chances of leakage from imperfect work, would thus occur within the walls.

The material for drains within the walls should be metal in all cases. It is often customary to lead a drain across under a basement floor by stoneware pipes, which, though much better than the old-fashioned brick drain, is far inferior to iron. Cast-iron pipes, with leaded joints, well calked, and painted, are safe, and, unless subjected to such great changes of temperature as might loosen the joints by expansion and contraction of length, will prove satisfactory for a long term of years. If iron is used inside the walls, there is seldom anything to be gained by burying it under the cellar or basement floor. Such pipes should be readily accessible for inspection. If a little attention be devoted to the subject, they can generally be placed along some wall or partition, or hung from the ceiling, where their joints can all be readily seen, to be recalked and painted whenever necessary.

The drainage of the soil on which a house is built, if it consist of porous sand or gravel, will not require much attention, unless the level of the cellar be decidedly below that of most of the surrounding land, as in broad plains or valley-bottoms. When such cases occur, or when the soil is impervious, a porous tile-drain should be laid, three or four feet deep if practicable, with porous material over it around the bottom of the foundation-wall, with a delivery to the house-drain above its outside trap which disconnects it from the sewer. In case no sewers are provided, among a scattered population, such a drain can generally be led to some point low enough to discharge it on the surface of the same lot; if not, the lot is very ineligible for building purposes.

Branch drains from sinks, wash-trays, and wash-bowls are generally made of lead, which seems to be the most suitable material. Its pliability and durability are valuable qualities. The first may lead to its distortion of form by sagging, if not well supported. Where these lead waste-pipes enter the iron ones, a common practice among plumbers is to secure the joint by glazier's putty. The only proper way to make such a joint is to solder a tinned iron or brass ferrule to the outside of the lead pipe, which is to enter the bell of the iron pipe. This ferrule gives a stiff material against which a lead joint can be calked in the same way as between two pieces of iron pipe. This lead packing will yield to the expansion, without breaking or crumbling. When lead traps are used under water-closets, the joint between them and the iron soil-pipe should be secured in the same way.

Soil-pipes from water-closets were formerly made of lead, at first by soldering sheet-lead into cylinder form, and afterward by the seamless process. The first show more rapid corrosion at the solder-joint; both are subject to corrosion and sagging, and to being gnawed by rats. Iron is much safer, and fortunately cheaper also, and is therefore now generally used.

Plumbers sometimes connect branching soil-pipes by T-joints, when it serves their convenience. Y-joints should always be used, for the same reasons as given above for connecting outside drains. The Y-joint sometimes requires the introduction of another small bend to complete the necessary change of direction. Hence arises the temptation to use the T-joints in contract-work, to save the cost of the bend and its application.

Rain-water cisterns are sometimes built in basements, or outside of houses, underground, having their overflows in the house-drain. Such an arrangement is never safe. However carefully the overflow may be trapped, the long droughts of our climate may dry up the water-seal, and allow the sewer-gas to spread over the water and be dissolved by it. Moreover, the drain may be obstructed below the junction of the overflow, and the whole house-sewage is then backed up through the overflow into the cistern.

There is a value in the grease now thrown away in dish-water which ought to lead to its being collected before going into the water, instead of encumbering our house-drains with it to such an extent as is now done. The best plan yet devised for keeping it out of the pipes is, perhaps, a small brick tank, laid in hydraulic cement, and plastered smooth inside, placed as close as possible to the cellar-wall on the outside, with the sink as close as possible to the same wall on the inside, so that the grease shall not congeal in the pipe between the two. (See Figs. 1012 and 1013.) For small and medium houses it should be from 1½ to 2 feet square on the inside, with the bottom about 2 feet below the outlet-pipe, which is to turn down about a foot on the inside, with a smooth, round turn, so that its mouth may be so much under water. The inlet should be about 6 inches higher than the outlet-pipe, to allow the grease to collect to that thickness above the water-line, which is governed

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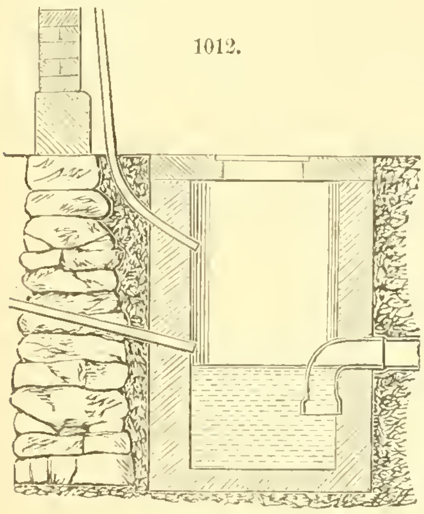

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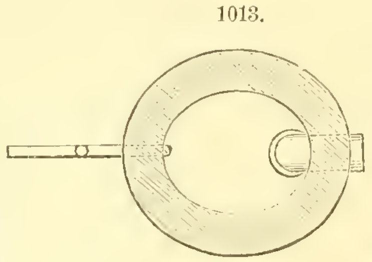

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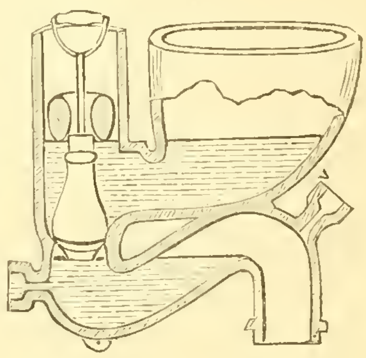


by the level of the outlet, without obstructing the mouth of the inlet. The grease will then float on the water, and become congealed in the form of a dirty scum, while the water and other matter in suspension will flow out by the mouth of the outlet, about a foot below the surface. The whole must be so placed as not to freeze. The depth needed for this will depend largely upon the exposure. The walls, being built on the surface of the ground, can be covered with a flag-stone, with hole and iron cover. The soil-pipes from the water-closets should by no means enter this receptacle. It should be upon a branch drain, serving the kitchen and scullery sinks alone, having its outlet into the principal drain. If more than one sink delivers into it, the tank itself should have a vent-pipe, to prevent the air, compressed by the influx of water from one sink, from being forced up through the trap of the other inlet-pipe into the house. If the waste-pipe becomes choked with grease between the sink and cess-pool, as will often happen when the fall is not rapid, it may be sometimes kept clear by flushing occasionally with boiling water, provided the passage be not wholly obstructed.

A water-closet, Fig. 1014, made by George Jennings of London, has accomplished the much-desired end of dispensing with the pan entirely, together with the air-space between the bowl and the lower trap. It also dispenses with a separate trap below, having such a trap in itself, made in connection with the bowl, all in one piece of crockery. Its water-supply is taken directly from any supply-pipe, adjustable to the actual pressure, so that no separate tank, service-box or valve, wires or cranks, are needed. There is a flap-valve, made of a rubber disk, rendering all back-flow impossible, and opening only with the pressure of water. Ample flushing of the bowl is secured by having the valve worked by a float, so that it remains open till the water reaches the prescribed level in the bowl.

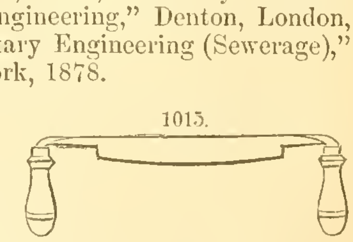
The requirements of a good water-closet, according to Bayles, are: that it should be inodorous; it must be abundantly and frequently flushed; it must be strong, simple, and not liable to get out of order; and it must be sealed against the outflow of air-currents from the sewer and soil-pipe. The same authority says: "It is simply impossible to maintain a clear and efficient water-seal in any trap discharging into an unventilated sewer connection. Water offers no effective resistance to the passage of impure air or light gases; and unless these are afforded an easy and direct outlet from the sewers and drains in which they form, they will not be held back so long as there is nothing to prevent their escape except a small quantity of water, which will eagerly absorb and as readily transmit them."

*Works for Reference.*—"Drainage of Districts and Lands," Dempsey, London, 1872; "Drainage of Towns and Buildings," same author; "Plumbing," Buchan, London, 1876; "Sanitary Work in the Smaller Towns and Villages," Slagg, London, 1876; "Sanitary Engineering," Denton, London, 1876; "Water-Supply of Cities and Towns," Humber, 1877; "Sanitary Engineering (Sewerage)," Latham, 1878; "House-Drainage and Water-Service," Bayles, New York, 1878.

DRAINER. See Paper-making.

DRAWING-FRAME. See Cotton-spinning Machinery.

1015.



DRAWING-KNIFE. A blade having a handle at each end, as shown in Fig. 1015, and used by coopers, wagon-makers, and carpenters. It is usually operated in connection with a shaving-horse, which holds the stave, spoke, or other article upon which the shaving cut is being made.

DREDGING MACHINERY. Dredging is effected in various ways—either by drags, or scoops, or rakes, or machines. There are two sorts of hand-drags, one for raising mud, the other sand. The first consists of an iron box pierced with holes, open in front as well as at the top; to this is attached a slightly flexible handle, of a length proportionate to the depth it is to work in: when this is made use of, the men in a boat make the iron box enter the sand, sustaining the handle

on the shoulder; and when it is filled they raise it, and, if there be any large stones, they are disengaged by means of hooks. One man will raise in this manner, where the depth is not more than 4 or 5 feet, a cubic yard in the course of a day, and sometimes more.

The drag for mud is differently formed: it is an iron ring, to which a canvas bag is attached, by passing a cord through holes made in the ring purposely to receive it; that point of the iron rim which is intended to touch the ground and enter the mud must be sufficiently strong. Two men in a boat or punt are required to manœuvre it, and in the course of a day they will raise from 12 to 14 cubic yards, if the depth does not exceed 6 feet; when the boat is made use of, it is first moored in such a manner that it cannot drift. Such a drag allows the water to flow out of it, and retains only the solid matter.

*The Louchette*, a kind of spade, or a collection of them, is used for cutting or extracting turf under water, without the necessity of first pumping it dry. This consists of a light iron frame, which is armed all round with a cutting-blade, in length about 3 feet; the part between it and the handle is open, being formed of four horizontal rods and two vertical ones; these receive the turf after it is cut and detached, and enable the workmen, by means of a rope and windlass, to pull it up. These cutting instruments have a variety of forms given them to adapt them to the peculiar work they may have to perform.

*The Box Shovel* consists of an open box fixed at the end of a long handle, usually made of iron; the cutter traverses in a groove, and is worked by another handle; by this the turf is cut and detached, and each successive piece falls into the box. As many as four turfs may be thus drawn up at one time.

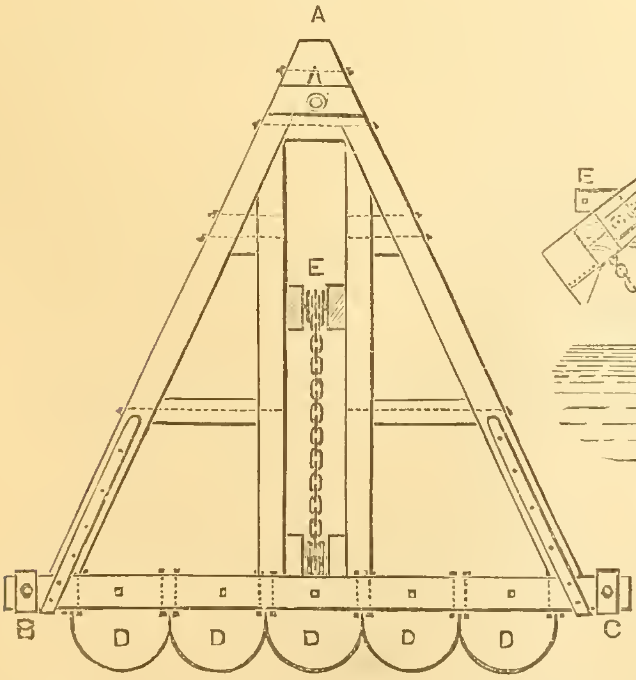
*Dredging Machines* have been constructed in various ways, and of iron or wood, according to the nature of the service. Some machines have been arranged so that the system of chain and buckets should work through a channel in the middle of the vessel; others with one system on each side; and others with the buckets working over the extremity of the vessel.

The best adapted boilers and engines for dredging purposes are those upon the marine principle, as in them compactness and stability are combined; and for this reason those of that description are invariably applied; but in practice it is found disadvantageous to the profitable working of the machine, if the engine be not of a proportionate power to the depth of water, the buckets of a suitable number, and the bucket-frame of sufficient length to lie at a proper angle. Hence the following arranged proportions are annexed as the best adapted for working at or about the various specified depths from which the material is to be raised:

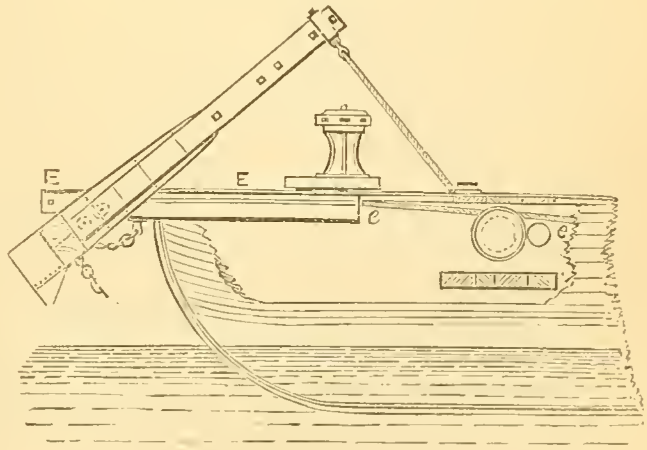
| Nominal Power of Engine. | Length of Bucket-Frame. | Number of Buckets. | Depth of Water in Feet. |
|---|---|---|---|
| 20 | 59½ | 34 | 18 |
| 25 | 63 | 36 | 20 |
| 30 | 78¼ | 45 | 25 |

The boat requires little or no peculiarity of form, otherwise than that of proper stability. It must be strong and well put together, or a constant tremulous motion is created by the action of the machinery, and the proper effect of the machine in a measure destroyed. It must also be of magnitude sufficient for the receiving of the machinery with a proper clearance for the buckets,

1016.




1017.




according to the depth of water and different positions in which, on that account, they are so frequently required.

*The Scraping Dredger.*—The action of the scraping dredge in forming river-channels is twofold: first, it cuts up and loosens the material of which the bar is composed, and second, conveys it down stream and deposits it in deep water. Figs. 1016 and 1017 represent the scraper devised by Colonel S. H. Long, U. S. A., and used in the improvement of the Mississippi river. The scraper frame, which carries 5 buckets, as shown at *D* in Fig. 1016, is supported by a heavy bowsprit, and is raised and lowered by a hori-

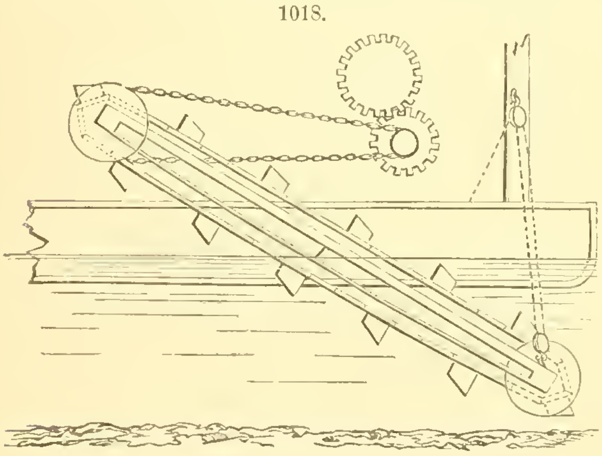
zontal drum actuated by a hoisting engine. In operation the wheels of the steamer are turned backward in a direction to drag the scraper across the shoal, the steamer moving stern foremost with the current of water, if there be any such current. Having been dragged entirely across the shoal, the scraper is hoisted out of water, and the steamer returns bow foremost to the place of beginning. The steamer was 210 feet long and of 484 tons measurement; scraper, 16 feet base, 16½ feet high, with 5 buckets or cutters, weight about 2¾ tons.

*Single-Bucket Dredger.*—A dredge of this type, constructed by Morris & Cummings of New York, is built as follows: The two parts of the bucket are hinged at their upper inner corners, and from their outer sides the rods or links extend to a cross-bar, the ends of which work in guides. When this cross-bar is raised in the guides, the two parts of the bucket are caused to open from each other, while, when it is caused to descend, the two halves are forced together, and caused securely to hold any materials contained within them. The raising or lowering of the cross-bar in its guides is effected by two chains, both of which pass up over pulleys at the end of the crane jib, and down to the hoisting machinery, each chain being led to an independent barrel. One of these chains is attached directly to the cross-bar above mentioned, while the other, before being connected to that bar, is led round a pulley placed beneath it. While the bucket is being lowered it is suspended by the first-mentioned chain, and the cross-bar is raised in its guides, and the two parts of the bucket are kept apart. As soon as it reaches the bottom the strain is brought upon the other chain, and the cross-bar is thus hauled down in its guides, and the parts of the bucket are closed before the latter is raised toward the surface. The hoisting machinery consists of a pair of horizontal engines, which, by means of a friction-clutch, can be made to drive either chain-drum at pleasure. The bucket is guided during its descent by a pair of wooden poles attached to the guides of the cross-bar, these poles working through eyes fixed near the top of the cross-jib. After the bucket has been raised the jib is swung on one side, so that the contents of the bucket may be discharged into lighters or any other receptacle for the dredged material.

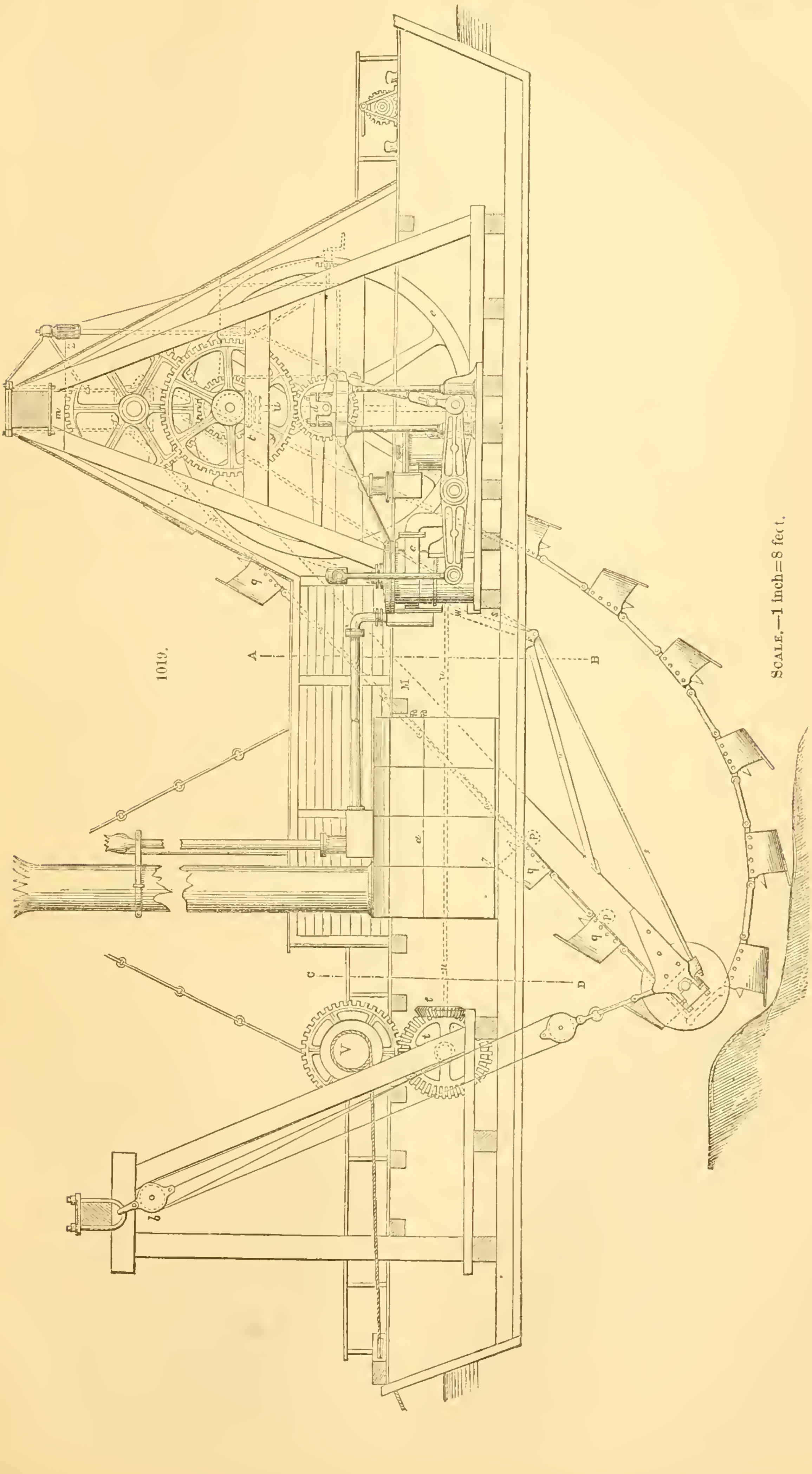
*Bucket-Train Dredger.*—The general arrangement of this type of dredger is exhibited in Fig. 1018. The essential feature is the endless chain, with scoop-buckets placed in a frame, which may be raised or lowered through a well in the middle of the scow upon which the apparatus and machinery for moving it are placed.

Fig. 1019 represents in detail the construction of a dredging vessel of this description. *a* is the boiler, constructed with internal fireplaces and flues similar to the boilers commonly used for marine engines. *b*, steam-pipe leading from the steam-chest on the boiler to the engine. *c* is a condensing engine of 20 horse-power, the cylinder being 27 inches diameter, and the length of stroke of piston 2 feet 9 inches. The engine is constructed with side-beams on the marine principle, and the motion is communicated to the fly-wheel shaft *d* by a connecting-rod in the usual way. *e* is the fly-wheel. *p*, Fig. 1020, is a friction-hoop, which fits lightly on a drum or sheave keyed fast on to the fly-wheel shaft, the use of this contrivance being to prevent accidents to the machinery, in case the buckets should get entangled with anything during the process of dredging, as, when the resistance increases beyond what is necessary for raising the soil, the drum or sheave slips round inside the hoop, and the buckets cease to work, while at the same time the steam-engine may continue its motion without injuring the machinery. *g* is a pinion bored to fit the fly-wheel shaft (but not keyed fast to it), having two strong stops, as shown, cast on one side of it, which come in contact with corresponding stops on the wrought-iron ring or hoop. *h* is a spur-wheel, which is driven by the pinion *g*. *i* is a pinion keyed on the intermediate shaft, which drives the spur-wheel *j*, keyed on the tumbler-shaft. *l l* are clutch-couplings for the purpose of connecting one or both sets of buckets to the steam-engine, or disengaging them when required. *m m m m* are cast-iron carriages, forming joints or hinges for supporting the bucket-ladders independent of the tumbler-shafts. *n n n n* are the tumblers over which the chain and buckets work. *q q q q*, etc., are the buckets, made of boiler-plate, and bolted securely to the links of the chain: the bucket-chain runs on cast-iron rollers *p p*, Fig. 1019. The bucket-ladders are made partly of wood, having wooden sides with cast-iron king-posts and transverse trusses, and wooden struts and wrought-iron tie-bolts, with screws at the ends, so that they may be tightened up when required. These ladders are remarkably strong, with comparatively light materials.

1018.



The spout *g*, Fig. 1020, is of wood, lined with sheet-iron, and has a joint to allow of the punts or barges being equally loaded on both sides without turning them round. When the outer end of the spout is raised by means of the purchase *z*, the soil will escape at the joint near to the side of the barge which is close to the dredging machine; and on lowering the outer end of the spout, the soil will be carried over to the other side of the barge, thus insuring its being equally loaded. The bevel-wheels *t t t t t* and shafts *u u u* convey the motion from the steam-engine to the apparatus on deck for propelling the vessel to and fro, raising or lowering the bucket-ladders, etc. The ladders are raised by chains passing round the barrels *v v*, and working in the sheaved blocks *b b*, which are suspended from the timber framing. The operation of raising the ladders is effected by connecting the barrels to the shafts by the clutches, which are worked to and fro by levers that pass through the deck of the vessel. When the ladders require lowering, the clutches are drawn back and the ladders



1019.

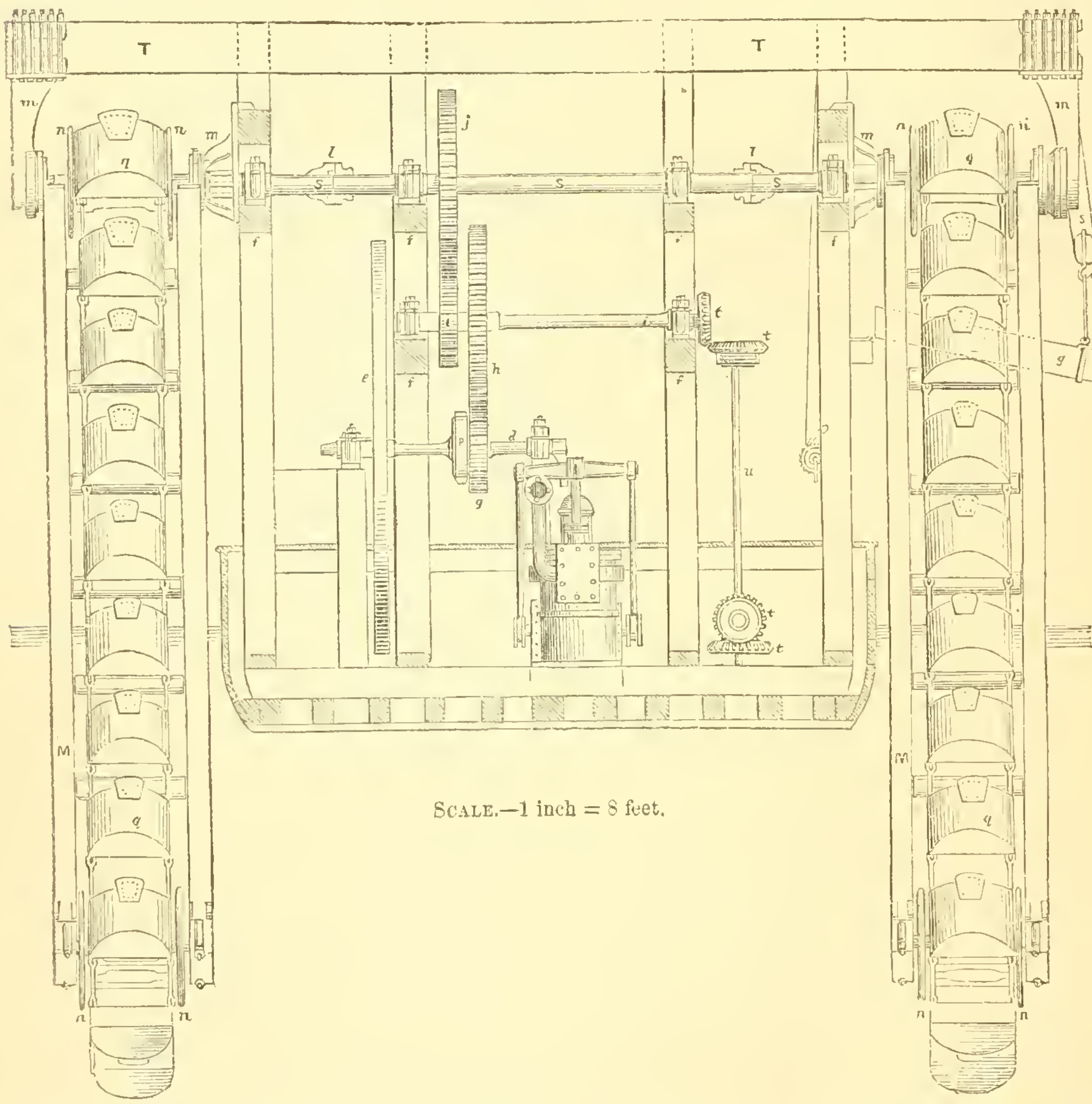
SCALE,—1 inch=8 feet.

run down of themselves to any depth which is desired, being regulated by a brake attached to the drums.

The apparatus for propelling the vessel is fixed on the deck, where there are two curved cast-iron barrels. By taking two or three turns of a rope or chain round these barrels, one under and the other over, one of the ropes will draw the vessel ahead, while the other pays off the slack, and *vice versa ;* or by putting both ropes or chains the same way round these barrels, they will both act in pulling the vessel in the same direction. It should be mentioned that there is a friction-sheave placed between the propelling machinery and the steam-engine, similar to that which is fixed upon the fly-wheel shaft, to prevent the chains or ropes from being broken in case of any obstructions.

The bucket-ladder, Fig. 1020, is composed partly of timber framing. To give it strength to bear

1020.

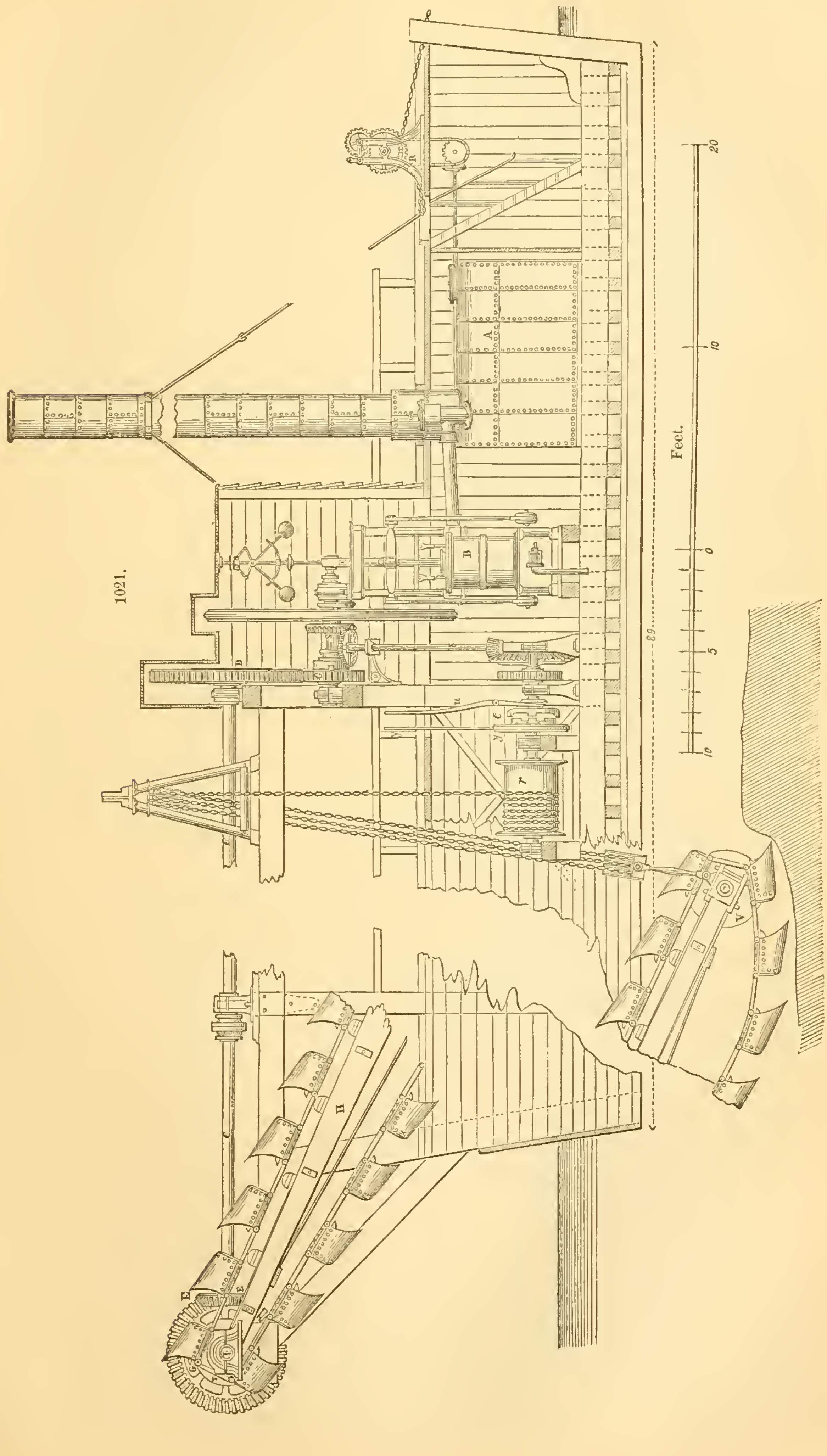


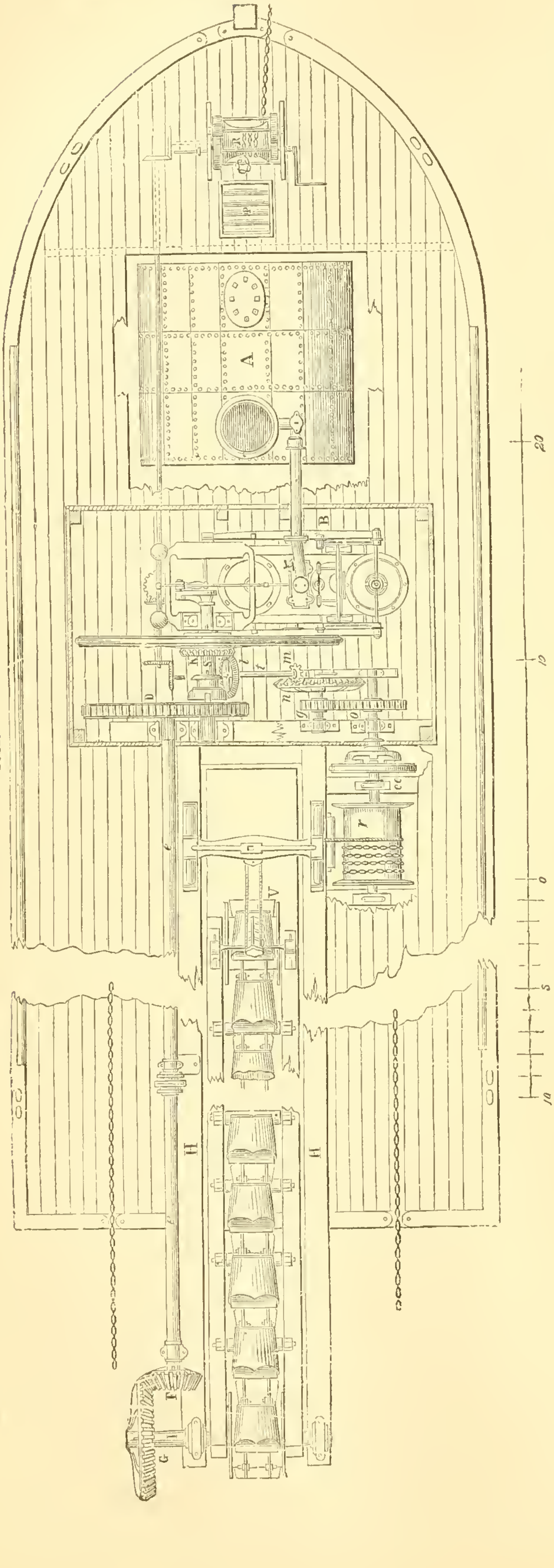

the weight of the buckets with their contents, it is furnished with a cast-iron king-post having two-inch tie-bolts connected to its lower extremity by a single and double forked joint, through which joints and the king-post a pin passes, thus firmly uniting them at this point. The other ends of the tie-bolts pass through snugs, cast on the top and bottom carriages at ends of ladder, and are furnished with a screw for the purpose of setting them up, by means of a nut, should they at any time become slack. There are also two wooden trusses, which take the strain of the framing, midway between its centre and either end. This ladder is found sufficiently strong, and well adapted for sustaining a heavy weight ; at the same time it is extremely light in appearance.

The buckets are made of boiler-plate, the back being half an inch thick. The back plate rises considerably above the other parts of the bucket, and slopes forward at an angle of about 25° toward the front or lip of bucket, for the purpose of retaining the soil and preventing its being spilled during its progress, after receiving it from the excavation, until it deposits the same in the barges alongside.

Figs. 1021 to 1023 represent the details of a dredging machine of like construction, built by Messrs. Girdwood & Co. of Glasgow, for the excavation of the river Clyde. *A*, Figs. 1021, 1022, represents the boiler, and *B* the engine, both of which are of the usual construction adapted to marine purposes. The cylinder of the engine is 26 inches diameter, length of stroke 2½ feet, number of strokes per minute 44, and requires about 2 cwt. of good coal per hour for the generating of a sufficient supply of steam. In effect, the engine will lift, from a depth of 18 feet, about 110 tons of mud or clay per hour, or 160 tons of sand or gravel in the same time ; but in very hard ground, and inter-

1021.






1022.

mixed with stones, no proper data can be given. The vessel is moved forward by the power of the engine, through means of the bevel-wheels, shafting, pitch-chain, etc., as shown in each design, and which communicates motion (when required) to and by means of the double-acting winch $R$; and, when the buckets are working in mud or clay, the vessel is caused to advance at the rate of about 4 feet per minute, when in gravel or sand $2\frac{1}{2}$ feet per minute, and the number of buckets delivered is 14 in that space of time.

With regard to the movement of the buckets, motion is given to the wheels $C$ and $D$ by the crank-shaft $S$ of the engine, and communicated by the line of shafting $e\,e\,e$, etc., to the wheels $F$ and $G$; from thence to the buckets by the barrel or tumbler $T$, that being made fast upon the spindle $I$, on which the wheel $G$ is fixed. The top or upper tumbler $T$ has 4 sides, and the bottom tumbler $V$ 5, as, when they are thus formed, the motion of the buckets is found in practice to work more steadily, and consequently the effects rendered more complete.

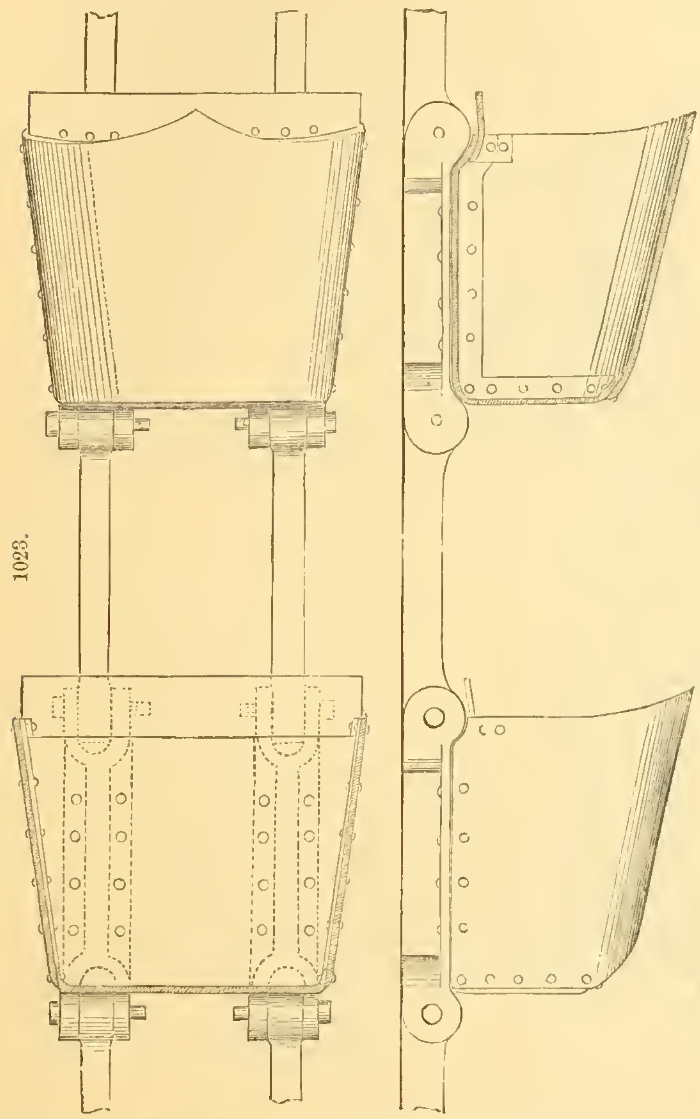
The bucket-frame $H$, acting upon $I$ as a centre, is also regulated to a proper depth of water by the power of the engine; the bevel-wheel $K$ upon the crank-shaft $S$ gives motion by means of the wheels $m\ n$ to the barrel $r$, round which the chain of the tackle passes, as shown distinctly in the elevation.

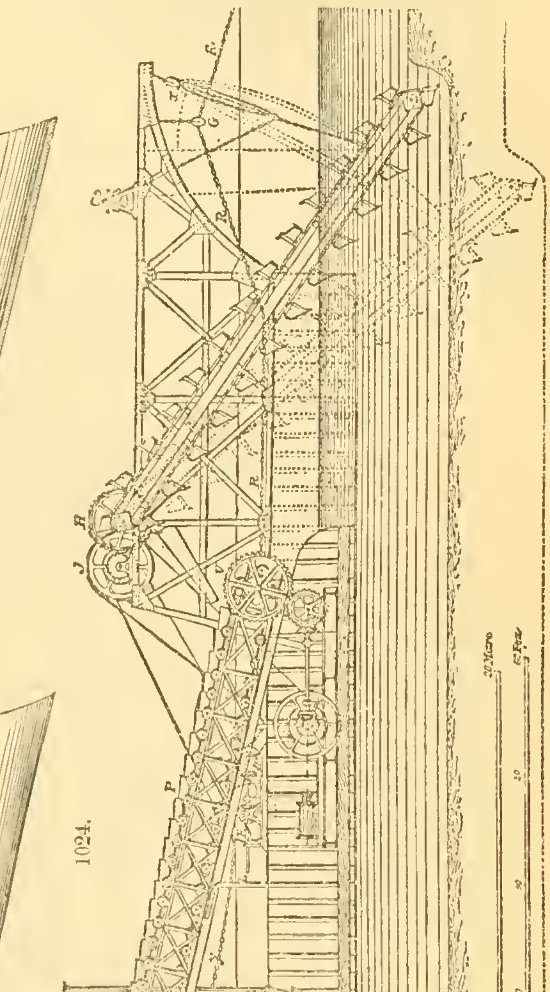
On the same shaft with the bevel-wheel $n$ is fixed a spur-pinion $g$, which gives motion to the wheel $o$; the motion is communicated (when required) by means of the clutch $c\ c$, and, when the frame $H$ is raised to a sufficient height, and placed at the requisite depth of water, further motion of the barrel is prevented through disengaging the clutch by means of the lever $W$, and the barrel rendered stationary by the lever and friction-pulley $y\ y$.

The bucket-frame is 55 feet 4 inches in length, and the number of buckets is 34, each bucket being $26\frac{1}{2}$ inches wide, 16 inches broad, 17 inches deep, and formed of plate-iron three-eighths of an inch in thickness. On the back or sole plate of each bucket, and immediately beyond its formation, is an attached piece or continuation of the plate, so as to form a covering to the joints of the links, and so prevent any injurious effects from the constant liability of contact with the excavated materials; also on the front of the buckets are fixed pieces of iron shod or edged with steel, for the purpose of increasing the strength of that portion of the

bucket, and the better adapting of the same for coming in contact with hard materials; likewise that of being easily removed when required for repair.

The links, etc., that connect the buckets, are of wrought-iron; all the joints and pins are cased


1023.


1024.

with steel and properly hardened; and rollers are provided for the proper conducting of the buckets along the frame *H*.

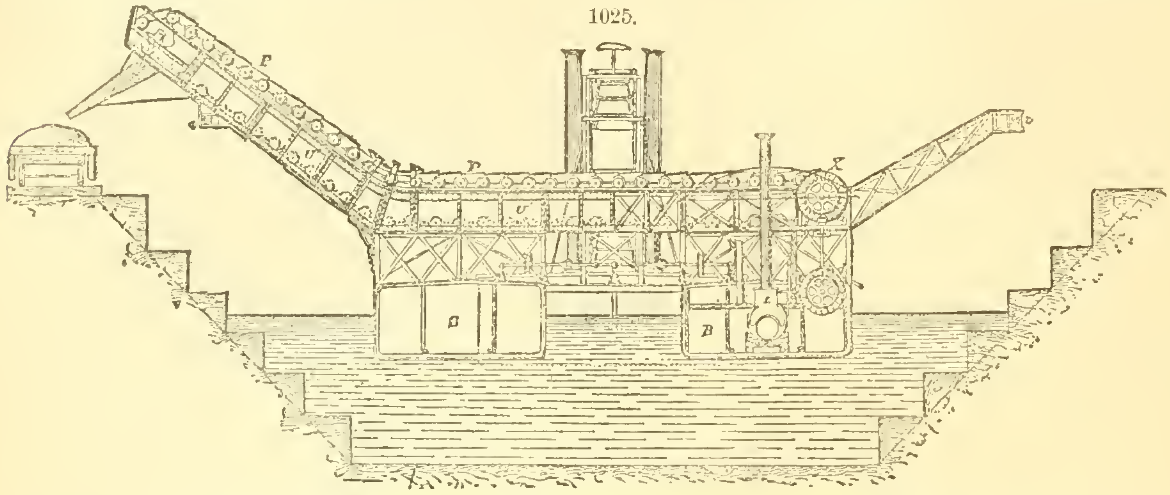
*Dredging at Lake Fucino, Italy.*—The machines used in the dredging of Lake Fucino, Italy, are represented in Figs. 1024 and 1025, and differ from ordinary types by the circular movement given to the fore part of the vessel which carries the train of buckets, and by the system of transporting the material excavated. In this circular movement, the forward part of the vessel being successively drawn from one side of the river to the other by the chains *R R*, the lower part of the chain of buckets describes a movement executed alternately from right to left and from left to right, and to such an extent that the chord of the arc is equal to the width of the canal. In this circular movement the vessel turns around a vertical axis *c*, fixed at the stern. This axis passes through a hinge, carried on a carriage *f*, running on rails attached to the forward ends of the two barges *B B*, which are firmly connected together. These barges are securely anchored to both sides of the canal by 4 chains, controlled by winches.

The carriage is composed of 8 double-flanged wheels, running on a frame and embracing a bar on each side. From the middle of the frame projects a horizontal bracket, on which are mounted two pulleys, with semicircular grooves, and running free on their axes. The movement of these pulleys, and the arrangement of the carriage, allow the axis attached to the dredge to adapt itself with facility to the various motions given to it in the course of the work. It may be remarked here that, the width and depth of canal being given, the size of the apparatus, whenever practicable, should

be adjusted to the size of the work in such a manner that the axis $e$ should always remain in the centre-line of the work, and the whole width can thus be dealt with continuously.

The buckets empty their contents on an endless chain $P$, composed of articulated receivers, and placed in the longitudinal axis of the dredge. This chain is moved by drums placed at the ends of a lattice-girder $U$, on which are laid the iron rails, one above and one below, for the endless chain to travel upon. The lower drum is driven by the wheel $V$, mounted on its shaft, and to

1025.

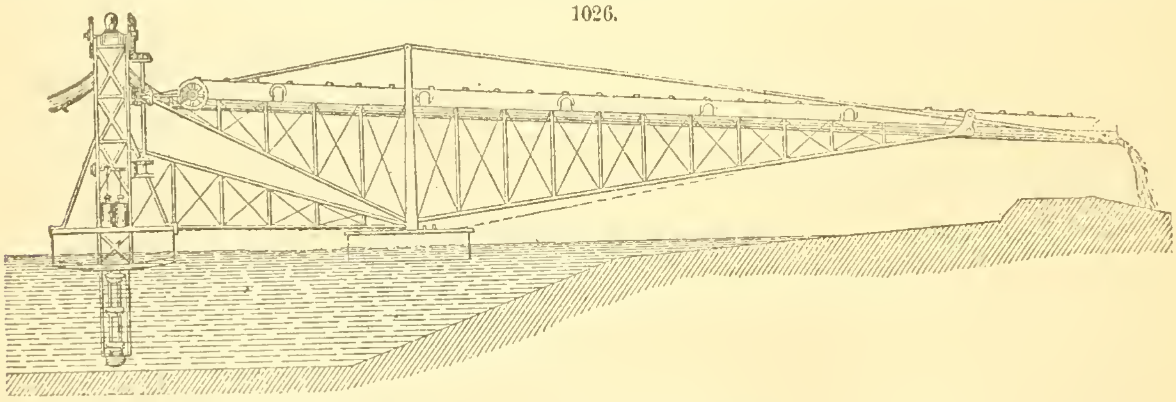


which motion is imparted from the engine. The endless chain of receivers empties the material excavated on to a similar chain $P'$, placed like the former on a lattice-girder $U'$, and carried by the two barges $B$ $B$. This chain, situated at right angles to the axis of the canal, empties the material into wagons on a railway laid on the bank; the chain is moved by the wheel $X$ on the lower drum shaft, and driven by the portable engine $Z$. The lattice-girder $U'$, carrying the chain $P'$, is of the form shown. This arrangement was adopted so that the excavated material could be discharged on to the canal bank when the water level fell below the ground level on each side.

The following results were obtained per day of 10 hours: The speed at which the machine is driven is equal to 17 buckets per minute, and the buckets are of such a capacity (about 5.25 cubic feet) that the total amount excavated is about 2,000 cubic yards; allowing 33 per cent. for loss, which is excessive, the effective work of 10 hours per day is 1,330 cubic yards.

*Dredging at Suez Canal.*—The great dredges used in the excavation of the Suez Canal had each a single line of dredge-buckets, supported at the centre. The iron hulls were from 72 to 82 feet in length. Two methods of delivering the excavated material were employed. In the first, Fig. 1026,

1026.

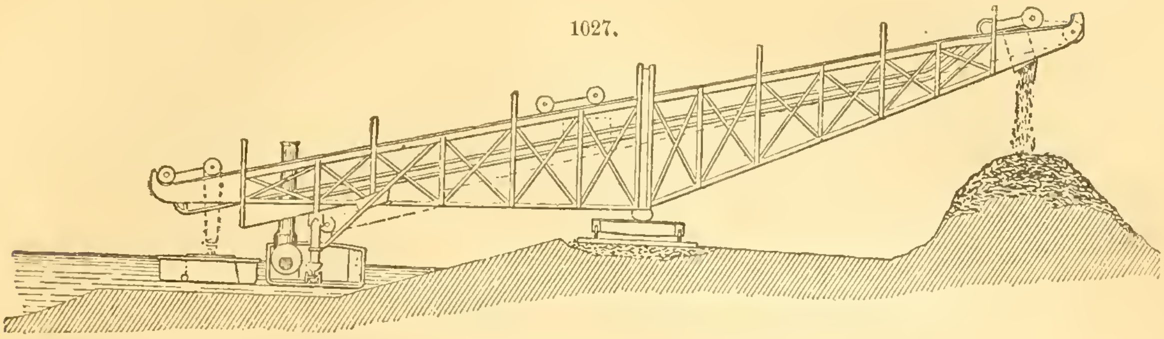


chutes 230 feet long were sustained by lattice-girders, and supported upon a barge moored parallel to the side of the dredge, upon telescopic frames, so that they could be raised or lowered at pleasure by means of a hydraulic hoist, and thus might be inclined at different angles. Rotary pumps in the dredge forced a stream of water into the upper end of the chute, so as to wash the soil down the slope. An endless chain furnished with scrapers was also made to move along the bottom of the chute whenever the materials were too stiff to be freely discharged by the aid of water.

The second arrangement was a portable inclined railway, Fig. 1027, extending from the dredge or barge upward over the banks, and upon which trucks or trollies carrying the boxes filled with the excavated material were made to ascend, and finally to dump their contents at the further end. The boxes were hooked on to the trollies as shown in the illustration.

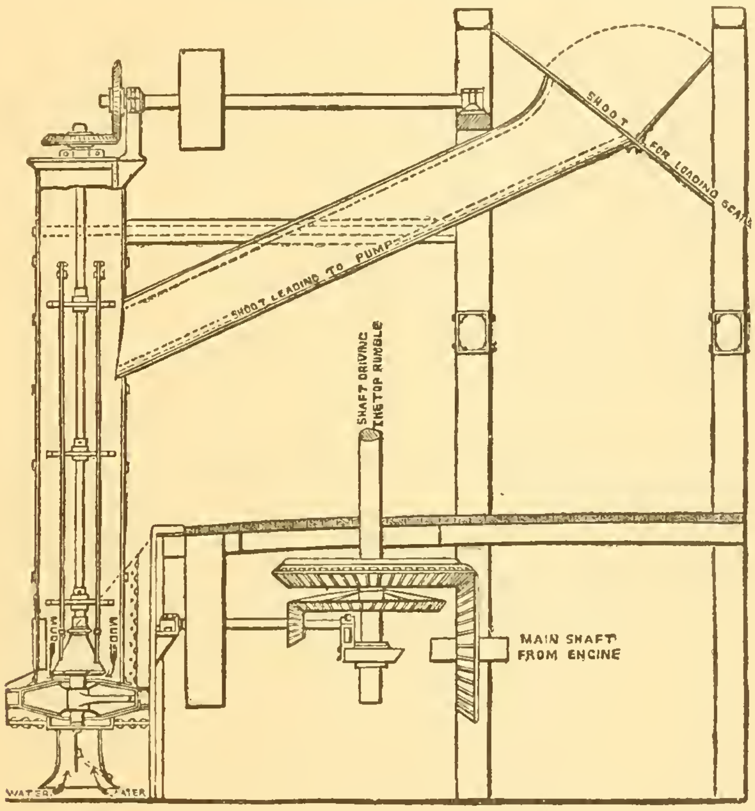
*Centrifugal Pump System of Dredging.*—Fig. 1028 represents the application of a centrifugal pump to dredging purposes, used in Holland. The pump is bolted to the side of the dredger, and is driven at the rate of 230 revolutions per minute. It has two inlets protected by valves, the one on the bottom for the admission of water, and the other on the top for regulating the entry of the material to be transported. On the top of the pump is placed a cylinder or reservoir to receive, by means of a chute, the stuff dredged up. The dredger is connected with the shore by means of wooden pipes fitted with buoying pieces to enable them to float, and connected by leather joints, those immediately following the dredger being arranged on the lazy-tongs principle to admit of its free movement in

1027.



any direction. The action is as follows: By the revolution of the flyer $A$, a rapid stream of water is maintained through the pipes into which the dredged stuff is admitted through the pump by the

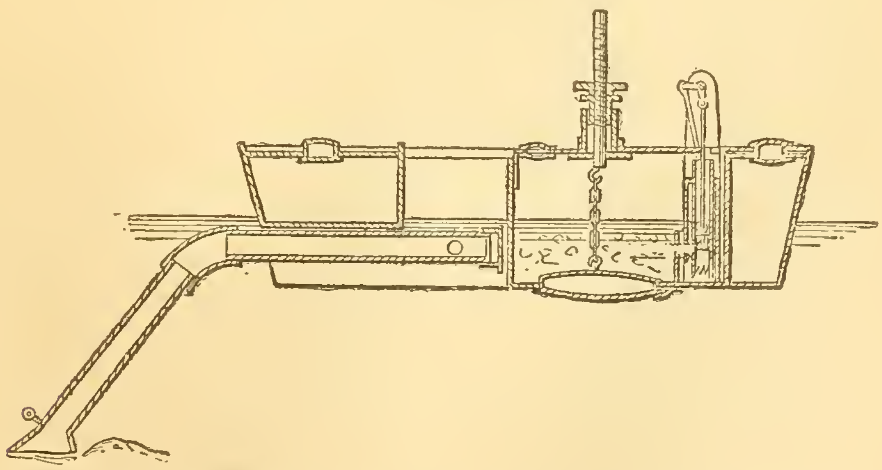
1028.




opening on the top, and is thus rapidly mixed and carried to the delivery at the opposite end of the pipes, where the heavier materials deposit themselves in nearly level beds.

*Air-Exhaust Dredger.*—Another mode of raising sand, silt, and mud is by an exhausted receiver in

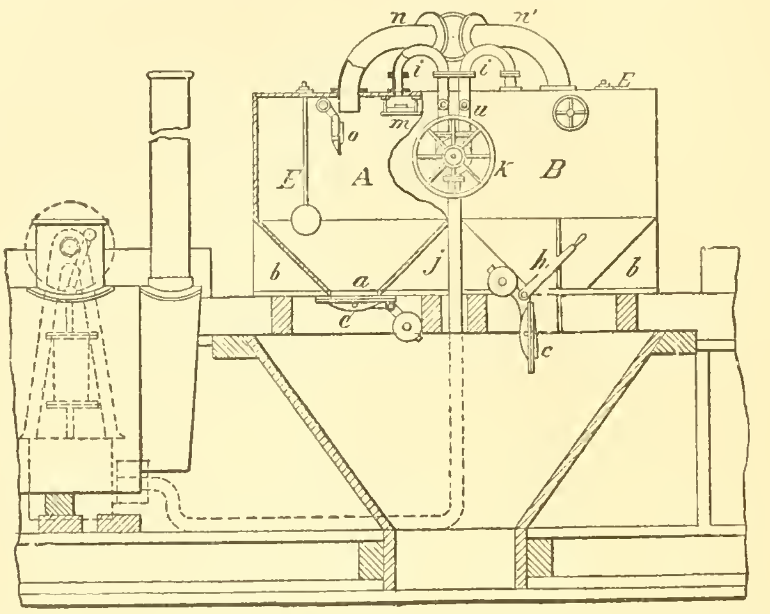
1029.



the barge, connected by an adjustable pipe and flexible connections with a spout which is adapted to suck in the mud (Fig. 1029), upon which it rests, and discharge it into the receiver for removal and subsequent discharge at the lower valve. The steam jet or ejector has also been proposed; it differs in no substantial respect from the water-ejector.

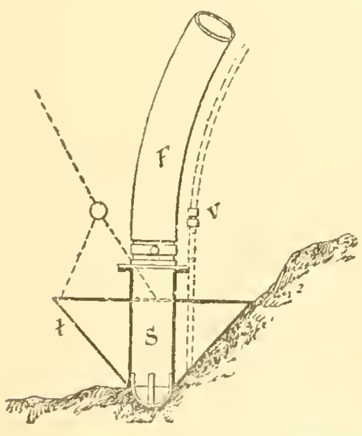
*The Pneumatic Excavator.*—As employed during the construction of the Tay Bridge, Scotland, this apparatus consists of four wrought-iron drums or tanks, *A B*, Fig. 1030 A, mounted upon a barge, and connected in pairs to obtain constant action with two air-pumps. They have a conically-shaped bottom, opening at *a*, through which the materials are discharged. The discharge-opening *a* is provided with a door *c*, made tight by a ring of India-rubber, secured between two circular iron disks. The method of connection of the valve or door with the lever enables the door to adjust itself when closed, so as to bed equally around the discharge-opening. This door may be opened or kept open, or be closed when necessary, by means of a hand-lever *h* fixed on a cross-shaft. One

1030 A.




pipe *i* passes through the cover of each tank *A B*. Both pipes *i i* are connected with a three-way cock, the shell of which is cast with three branches—the lower branch for connection with pipes *j*, which are in communication with air-pumps. In the interior of each tank, and immediately below the mouth of the pipe *i*, is mounted a valve *m*. This is a block of wood arranged to slide upon rods, which are secured to the cover of the tank. A disk of India-rubber is secured to the upper surface, or let into the top of the block. When the materials rise so high within the tank that the block becomes partly immersed, it floats; and if the influx continues, it is raised until it closes the pipe. An indicator *E* shows the height of the material in the tank. The curved pipes *n*, which are attached to the trunk *F*, Fig. 1030 B, are provided at their lower end with valves *o* for closing them during the emptying of the tank. The trunk *F* forms the suction-pipe, the end of which is provided with a nose-piece, and which may be moved about to any part of the caisson.

1030 B.

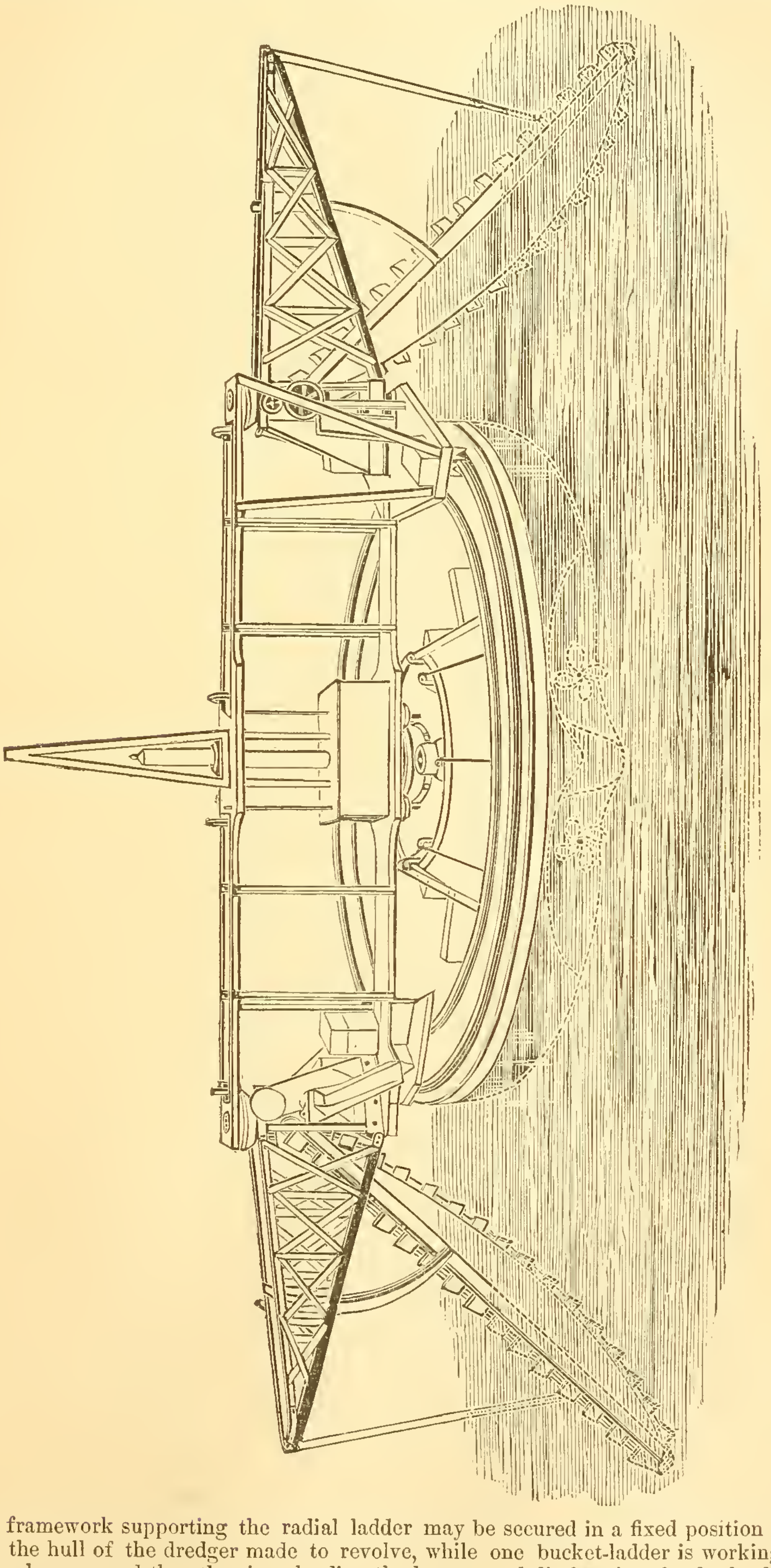



The action of the apparatus may be described as follows: One of each pair of the tanks *A* is in communication with the air-pump and with the trunk *F*. In the other tank the valve *o* is closed, and communication with the air-pump is shut off by the three-way valve. The pump will create a vacuum in the tank *A*, and the mud, gravel, and matters associated with water are sucked through the pipe *S*, Fig. 1030 B, and, ascending through the trunk *F*, flow into the tank. When the tank is sufficiently filled, the hand-wheel is turned so as to shut off the communication with the air-pump, and air is admitted to the interior of the tank by air-inlet cocks *u*. The valve *o* now closes. The door *c* is opened to connect the tank *B* with the air-pump, so that the latter tank begins to fill while the other tank is discharging; or the plug of the three-way valve may be first turned into position to establish a communication between the two tanks before opening the cock *u*, whereby a partial vacuum is at once formed in the tank *B*. The two tanks are thus filled and emptied alternately. To facilitate excavation or dredging at comparatively great depths, a jet of compressed air may be admitted into the mouth of the aforesaid suction-pipe by a pipe shown by dotted lines *V*. Two men and a boy are required for each barge, and the quantity raised per working-day of 10 hours averages upward of 400 tons.

Fig. 1031 represents a circular radial dredging machine, designed by Mr. W. R. Kinipple, C. E., for dredging afloat or aground without the usual aid of bow, side, and stern chains. This machine consists of a circular vessel having a round well or hopper, and a revolving framework carrying the engines, machinery, and radial bucket-ladders. In the centre of the vessel is a cylindrical screw-pile, which is screwed into the bottom of the sea or river, at any spot where dredging operations are to be carried on. The pile is hollow, and is filled with water to aid its descent by weight; the water is pumped out to give additional lifting power during the process of rising. Around the pile there is freedom for oscillation in a moderate seaway. There are two revolving anchors carried by legs, which are lowered down to the bed of the sea. These provide additional mooring power beyond

that obtained by the centre screw-pile, and are for the purpose of giving a rotary motion to the dredger when it is at work. On the deck of the hull, at the outer margin, is a rail, on which the radial dredging machinery revolves or travels. There are two radial bucket-ladders, which, when dredging, may be worked in opposition to each other, so as to place the machine in equilibrium.

1031.



The traveling framework supporting the radial ladder may be secured in a fixed position to a quay or wharf, and the hull of the dredger made to revolve, while one bucket-ladder is working radially and loading the hopper, and the other is unloading the hopper and discharging the dredged materials into an embankment behind the quays.

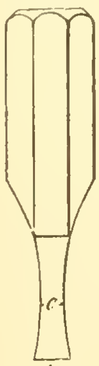
**DRESSER.** See Cotton-Spinning Machinery.

**DRIFTS.** Of drifts there are two kinds. One is a smooth, round, conical pin, employed by boiler-makers to make the punched holes in boiler-plates come fair, so that the rivets may enter. This is termed a stretching drift. The other is a toothed or cutting drift. The first tends to weaken the strength of the plate at the narrowest section of metal, namely, between the hole and the edge of the plate, where the latter, being the weakest, gives way to the pressure of the punch. Its use is not deemed compatible with good workmanship, and hence its description is omitted.

Of cutting drifts there are two kinds, the first being that shown in Fig. 1032. *A* is the cutting edge, the width and thickness at *C* and *B* being reduced so that the sides of the drift may clear the sides of the hole. The tools are filed at *A A* to suit the required hole, and tempered to a brown bordering upon a purple. The hole or keyway is then cut out roughly to nearly the required size, and the drift is then driven through with a hand hammer, cutting a clean and true hole. Care must, however, be taken to have the work rest evenly upon a solid block of iron or (for delicate work) lead, and to strike the punch fair and evenly; otherwise a foul blow may break the drift across the section at *C*. This class of drift is adapted to small and short holes only, such as cotterways in the ends of keys or bolts, for which purposes it is a very serviceable and strong tool. It must be freely supplied with oil when used upon wrought-iron or steel.

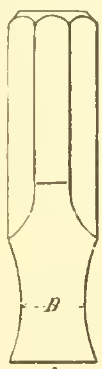
For deeper holes, or those requiring to be very straight, true, and smooth, the drift represented by Fig. 1033 is used. The breadth and thickness of the section at *A* is made to suit the shape of the keyway or slot required. The whole body of the drift is first filed up, parallel and smooth, to the

1032.



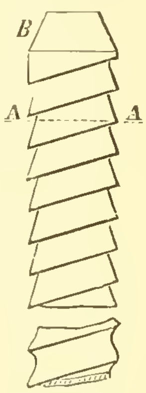

A

1033.

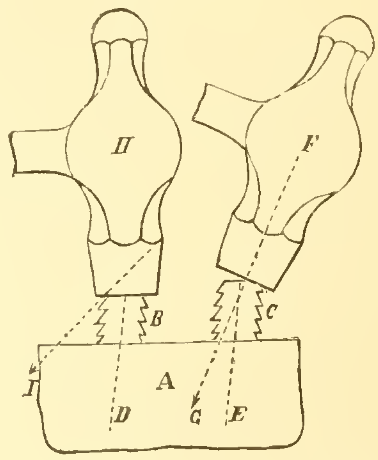



A

1034.




1035.




required size and shape; the serrations forming the teeth are then filled in on all four sides, the object of cutting them diagonally being to preserve the strength of the cross-section at *A A*, Fig. 1034. The teeth may be made finer (that is, closer together) for very fine work, their depth, however, being preserved so as to give room to the cuttings. To attain this object in drifts of large size, the teeth should be made as shown in Fig. 1034, which will give room for the cuttings, and still leave the teeth sufficiently strong not to break. The head *B* of the drift is tapered off so that, when it swells from being struck by the hammer, it will still pass through the hole, since this drift is intended to pass clear through the work.

The method of using this tool is as follows: The hole should be roughed out to very nearly the required size, leaving but a very little to be taken out by the drift, whose duty is, not to remove a mass of metal, but to cut a true and straight hole. To assist in roughing out the hole true, the drift may be driven in lightly once or twice, and then withdrawn, which will serve to mark where metal requires to be removed. When the hole is sufficiently near the size to admit of being drifted, the work should be bedded evenly upon a block of iron or lead, and oil supplied to both the hole and the drift; the latter is then driven in, care being exercised that the drift is kept upright in the hole. If, however, the hole is a long one, and the cuttings clog in the teeth, or the cut becomes too great, which may be detected by the drift making but little progress, or by the blow on the drift sounding solid, the drift may be driven out again, the cuttings removed, the surplus metal (if any there be in the hole) cut away, the hole and drift again freely oiled, and the drift inserted and driven in as before, the operation being continued until the drift passes entirely through the hole; for the drift will be sure to break if too much duty is placed upon it. After the drift has passed once through the hole, it should be turned a quarter revolution, and again driven through, and then twice more, so that each side of the drift will have been in contact with each side of the hole (supposing it to be a square one), which is done to correct any variation in the size of the drift, and thus cut the hole true. The great desideratum in using these drifts is to drive them true, and to strike fair blows, otherwise they will break. While the drift is first used, it should be examined for straightness at almost every blow; and if it requires drawing to one side, it should be done by altering the direction in which the hammer travels, and not by tilting the hammer face. (See Fig. 1035.) Suppose *A* to be a piece of work, and *B* and *C* to be drifts which have entered the keyways out of plumb, as shown by the dotted lines *D* and *E*. If the drift *C* on the right was struck by the hammer *F* in the position shown, and traveling in the direction denoted by *G*, it would be almost sure to break; but if the drift *B* was struck by the hammer *H*, as shown, and traveling in the direction denoted by *I*, it would draw the drift *B* upright without breaking it; or, in other words, the hammer face should always strike the head of the drift level and true with it, the drawing of the drift, if any is required, being

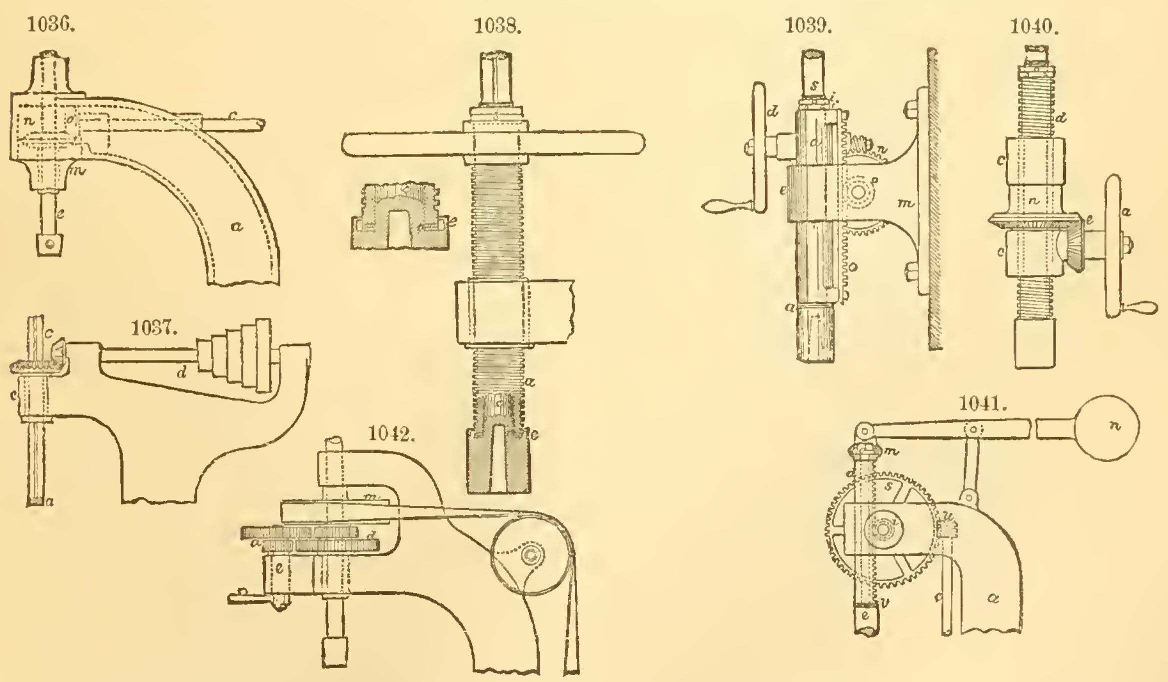
done by the direction in which the hammer travels. When it is desired to cut a very smooth hole, two or more drifts should be used, each successive one being a trifle larger in diameter than its predecessor. Drifts slight in cross-section, or slight in proportion to their lengths, should be tempered evenly all over to a purple blue, those of stout proportions being made of a deep brown bordering upon a bright purple. For cutting out long narrow holes the drift has no equal, and for very true holes no substitute. It must, however, be very carefully used, in consequence of its liability to break from a jarring blow. J. R.

DRILL-HOLDER. See LATHE TOOLS, and DRILLING AND BORING MACHINES.

DRILLING AND BORING MACHINES. Drilling differs in principle from almost every other operation in metal-cutting. The tools, instead of being held and directed by guides or spindles, are supported mainly by the bearing of the cutting edges against the material. A common angular-pointed drill is capable of withstanding a greater amount of strain upon its edges, and rougher use, than any other cutting instrument employed in machine-fitting. The rigid support which the edges receive and the tendency to press them to the centre, instead of to tear them away as with other tools, allows drills to be used even when they are imperfectly shaped or improperly tempered, and even when the cutting edges are of unequal length. Most of the difficulties which formerly pertained to drilling are now removed by machine-made drills, which are manufactured and sold as an article of trade. Such drills do not require dressing and tempering or fitting to size after they are in use, make true holes, are more rigid than common solid-shank drills, and will drill to a considerable depth without clogging. A drilling machine adapted to the usual requirements of a machine-fitting establishment consists essentially of a spindle arranged to be driven at various speeds, with a movement for feeding the drills; a firm table set at right angles to the spindle and arranged with a vertical adjustment to or from the spindle; and a compound adjustment in a horizontal plane. The simplicity of the mechanism required to operate drilling tools is such that it has permitted various modifications, such as column drills, radial drills, suspended drills, horizontal drills, bracket drills, multiple drills, and others.

The difference between the American and European practice in constructing drilling machines, stated in general terms, is that in this country belts are moved faster in proportion to the speed of the drill; the changes as to speed are the same, but on a different scale, and the tools are driven with more power and at a slower speed. This difference is in some measure explained by the fact that in American engineering establishments there are generally provided drilling machines of various sizes. Small holes are never drilled on large machines, and boring is never attempted on small machines.

With few exceptions, the driving gearing of American drilling machines approximates to the two types illustrated by the diagrams Figs. 1036 and 1037.* Fig. 1036 shows a method of encasing the spindle-gearing in the framing; *a* is the main column, *e* the spindle, and *c* the countershaft. The annular bearing *m* is turned to fit into the bottom of the circular cavity *n*, and when removed permits easy access to the pinion *o*. It may seem that this mode of arranging the gearing is more expensive, but when "fixtures," as they are called, are provided for boring the bearings, the work can be rapidly and accurately performed. The bearings are bushed with brass, so as to be replaced if worn; but, with surface enough and material of the best kind, there is but little wear, and it is best to avoid compensating caps, which may be either too loose or set up too close.




The form of framing shown in Fig. 1036 is symmetrical, and affords a good opportunity for mounting feed and back gearing on the shaft *c*. In Fig. 1037 the most novel feature is the adjustment of the spindle *c* through the bearing at *e*. This is a peculiarity of eastern-made drilling machines; its

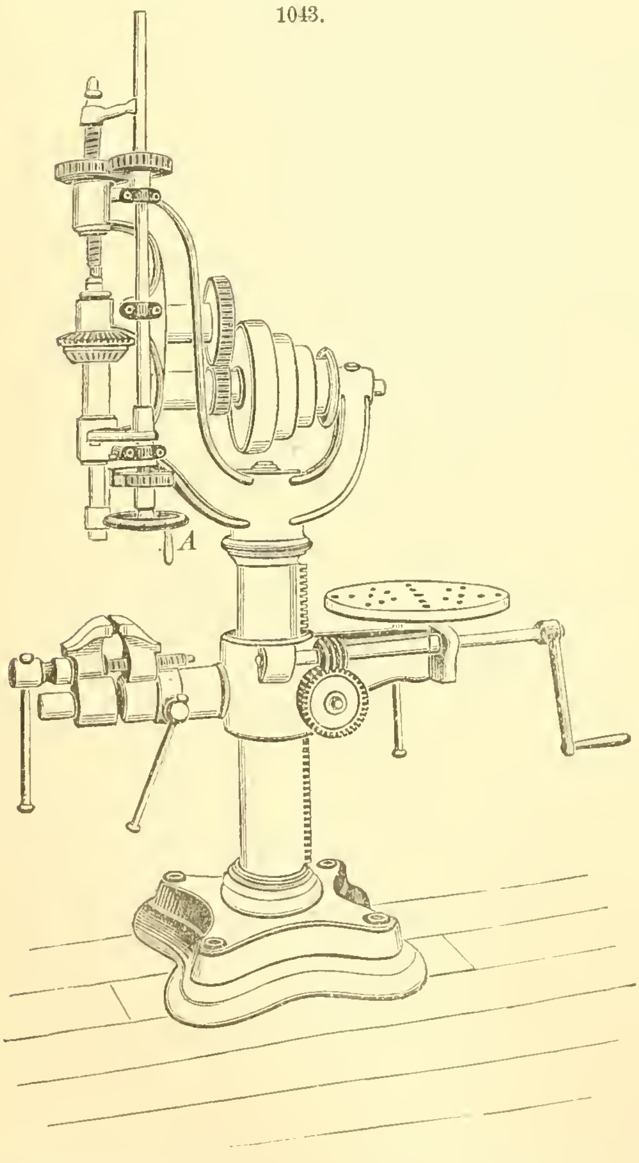
* *Engineering*, xxii., 198.

value in a practical way depends somewhat on the character of other machine tools in a workshop, and also upon the kind of work to be done. Such machines have a double adjustment for depth; the tables are arranged to be raised or lowered a distance of 2 feet or more, and the spindle adjustment is as much, so that a distance of 4 feet can be had between the table and spindle. A countershaft is generally mounted on the main frame beneath the shaft *d*, so that the belts can be conveniently shifted from one step to another. The long shaft *a* gives ample room for back gearing and feeding gearing, the whole being accessible, and yet high enough to avoid accidents in handling material.

Fig. 1038 shows the mode of resisting the thrust when a sleeve-screw is used. The end of the sleeve *a* rests on one or two washers of brass or steel at *o*, and projects within the cup-ring or collar *e* on the spindle *c*; by this arrangement oil thrown out by centrifugal force is arrested by the collar *e*, and, as soon as the drill is stopped and pressure removed, it again lubricates the bearing surfaces.

Fig. 1039 shows another device for feeding drilling-spindles. Here *a* is a sleeve sliding through the bearing *e* by means of the rack *c*, and a pinion at *o* inclosed within the bracket *m*. The pinion *o* is operated by a tangent wheel, as shown at *n*, and a hand-wheel *d* on the front; *s* is the spindle and *i i* are compensating collars. Thin washers of anti-friction material are placed between the end of the sleeve *a* and the spindle at *u*. The bracket *m* with its attachments is counterweighted, and slides up or down on the front of a main column for adjusting the height of the spindle, as explained in a former place. This arrangement is in some respects not as advantageous as the old and simple device shown in Fig. 1040. With this there are but half as many joints to produce lost motion; the hand-wheel *a* can be placed at the side or in front as may be preferred, and the power regulated by the proportion of the bevel-wheels *c*. *c c* are shells cast in a bracket, *d* is a screw-sleeve, and the wheel *n* has an internal thread. This mode of resisting thrust is in practice all that can be desired. The speed of the bearing surfaces is of course considerable, as they are in Fig. 1038; but in drilling the pressure generally diminishes as speed increases, or as drills of less diameter are used, so that a joint of this kind constructed of good material is durable and reliable.

1043.




Feeding mechanism is represented in Fig. 1041. Here *a* is an imaginary frame or column, *e* the spindle, *c* the feeding-shaft, and *d* a circular shell or sleeve flatted on one side and formed into a rack. This sleeve *d* is drilled through to receive an extension of the spindle, as shown by dotted lines. At the top of the spindle is a stirrup *m*, having an oil-cup to maintain a constant lubrication of the collar *o*, which sustains the weight of the spindle *e*. The counterweight *n* is made heavy enough to prevent loss of motion in the joints at each end of the sleeve *d*, and so that drills will not drop down for a short distance when they go through a piece, as is common when a counterweight is not used. The sleeve *d* is moved by a pinion at *i*, and this in turn by the tangent wheel at *s* and the worm-pinion *u* at the top of the feed-shaft *c*.

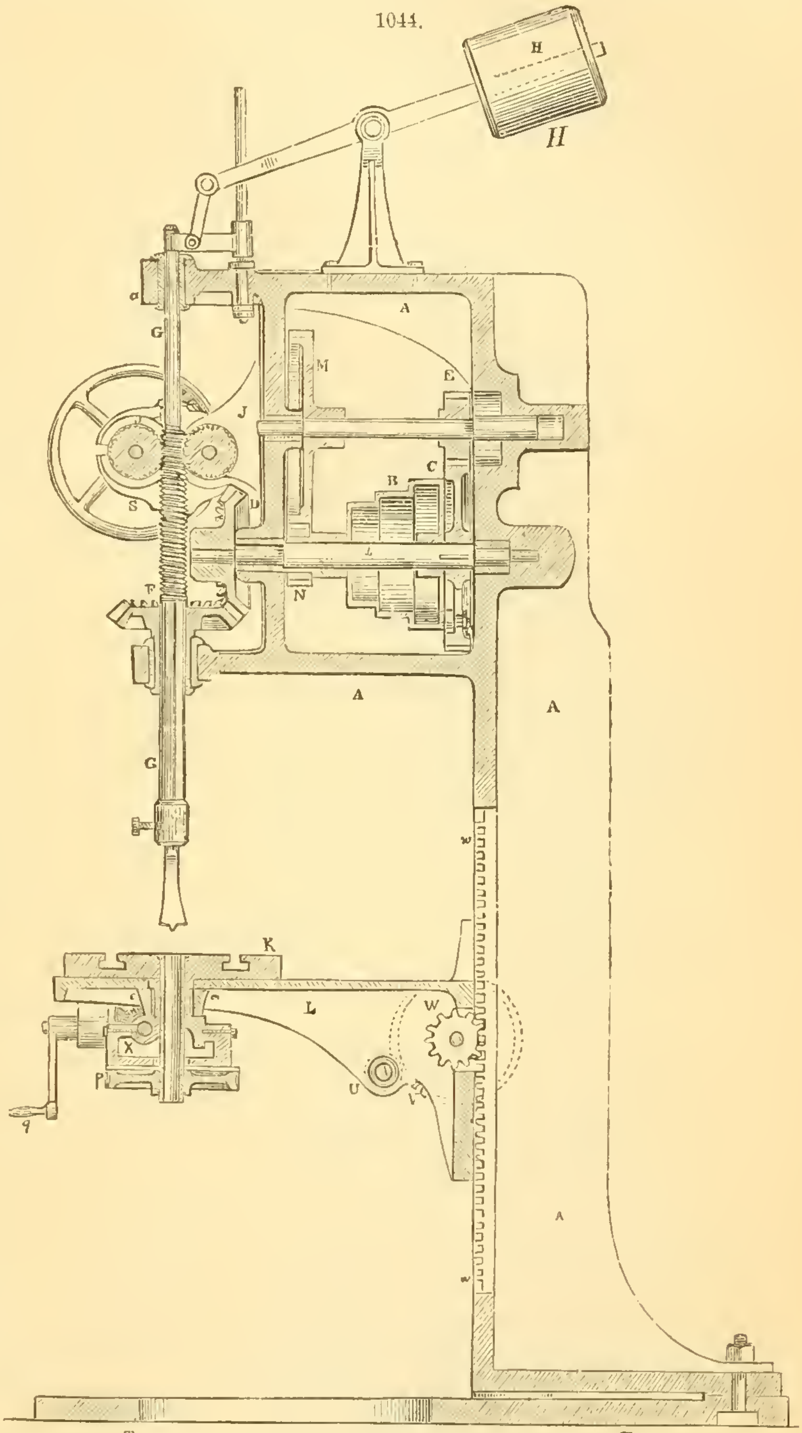
The mode of arranging back gearing shown in Fig. 1042 has been adopted for most American drilling machines. The end pairs of wheels, instead of being at each end of the step-pulleys, are placed together as shown in the diagram at *a* and *d*. The movable pair *a* are mounted loose on an eccentric stud *e*, and are thrown into gear by the handle *c*. The strain on the stud *e* is not severe, and is of a kind which permits a loose-running joint without much danger of wear.

*Vertical Drilling Machines.*—Fig. 1043 represents an improved vertical drilling machine of French construction. *A* is the feed-wheel, placed conveniently at the hand of the operator, and the drill is rotated at double speed from the belt cone-pulley. Upon arms of the sleeve which surrounds the supporting column is a parallel vise and a perforated table. By means of the crank, in connection with the worm and pinion and rack on the column, the work-holding attachment may be raised or lowered at will. The pressure on the drill is automatic. This machine weighs 1,232 lbs., and the diameter of the table is 23.4 inches.

Fig. 1044 exhibits the construction of a column drilling machine built by Sir Joseph Whitworth & Co. The framing *A* consists of a solid casting attached to the sole-plate *T*; and on the upper portion a bracket is cast, which serves to carry the outer ends of the cone-spindle and back-speed

spindle of the machine. Upon the spindle are the driving-cone $B$ of three speeds, the spur-wheel $C$, and the bevel-pinion $D$. The speed-cone $B$ is loose upon the shaft, and only communicates motion to it by means of the spur-wheel $C$, which is keyed upon the spindle, and to which the cone can be attached by a stud-pin and nut. This wheels gears with the pinion $E$, on the same spindle which carries the wheel $M$; this in turn gears with the pinion $N$, which is fast upon the end of the cone $B$, but runs loose upon the cone-spindle. This arrangement is in every respect the same as the ordinary back-speed of a lathe, and serves the same purpose. Supposing the back-speed removed, the cone being driven by its belt causes the spindle to revolve in consequence of its attachment to the fast-wheel $C$, and at the same time gives motion directly to the bevel-pinion $D$ on the end of the spindle. This again gears with the bevel-wheel $F$, on the drill-spindle $G$ $G$, which is free to slide vertically in the eye of the wheel, while at the same time it is prevented from revolving in it by a sunk feather. By this means three different degrees of quick speed may be communicated to the drill. But let the back-speed be in gear, as represented in Fig. 1044, and let the stud-pin be removed, and the cone thereby loosened from its attachment with the wheel $C$, the motion being communicated to it will not drive the shaft directly as before; but the pinion $N$, being fast upon it, will give motion to the wheel $M$, upon the same spindle with the pinion $E$. This last will therefore make the same number of revolutions as $M$, but being less in diameter will convey a proportionally less velocity to the wheel $C$, with which it gears, and which it consequently drives with a speed diminished in the ratio of the gearing pairs. Now the wheel $C$, being fast on the shaft, conveys through it to the bevel-pinion $D$ the same diminished speed, and this again to the drill-spindle $G$ $G$. This reduced speed may, of course, be varied as before, by placing the belt on one pulley or other of the speed-cone. Behind the pinion $E$ there is a recess cast in the framing, to allow it to enter when the back-speed wheels are to be thrown out of gear; and it may be remarked that this speed-gear is only required to be in action when the machine is employed in boring holes of upward of an inch and a half in diameter. The wheel $F$ is cast with a long hollow boss, which is turned, and fitted into a brass collar in the lower branch of the carrying-bracket, as seen. As already observed, the drill-spindle passes through the wheel $F$, which thus serves as its lower guide. The upper end of the spindle is at the same time guided in a collar similarly fitted into the upper branch of the bracket at $a$, and is thus guided vertically in ascending and descending. (In the drawings it is shown at the lowest limit of its travel.) To the top of the drill-spindle is attached the back-weight $H$ by a jointed lever and guide-link, which embraces the top of the spindle and moves upon a vertical guide-rod, kept firm in its place by having its lower end held by a screw-nut, in a socket cast in the bracket, in the manner of a bolt, a ruff forged upon the lower end of the rod answering to the head of the bolt. The drill-spindle is itself screwed toward the middle of its length; it is there embraced by two screw-wheels $J$ $J$, between which it turns, and which serve the purpose of a nut to feed down the spindle in the operation of drilling.

1044.



$K$ is the table upon which the article to be bored rests, and to which it can be firmly held down and adjusted by T-headed bolts and glands in the usual way, when thought necessary. The table, it will be observed, is recessed and grooved to receive and retain the T-heads of the holding-bolts. The table is itself supported upon the sole of the large carriage-bracket $L$, which has a vertical sliding motion, and is raised and depressed by means of a hand-crank applied at $U$. The table has a double movement upon the sole of the carriage-bracket; one movement is circular and the other is in the direction of the length of the table. The feed of the tool during the operation of boring is obtained, as before stated, by means of the two screw-wheels $J\,J$, by an arrangement of parts which forms the chief novelty of this machine. On the axes of these wheels are placed two pulleys, the circumferences of which are embraced by the friction-collars $S\,S$. The bearings of the axis being attached to the framing $A\ A$ of the machine, it is obvious that, the machine being in motion, if the pulleys be prevented from revolving, the wheels $J\,J$ will likewise remain at rest; but, the screwed part of the drill-spindle revolving between them, they will act as a stationary nut, and cause the spindle to descend through a space equal to one thread of its screw during every revolution. Again, suppose the pulleys and wheels free, the screw of the spindle, instead of descending, will simply cause the wheels $J\,J$ to revolve on their axes through a space equal to one tooth during every revolution of the screw. Now, between these extremes any amount of feed or downward motion of the drill-spindle may be obtained by simply retarding the motion of the wheels by means of the friction-collars $S\,S$, which embrace the small pulleys on their axes; for the friction of the collars being less than to prevent entirely the motion of the wheels, and at the same time greater than to allow a tooth to pass during a revolution of the spindle, a downward motion of the spindle must thus be produced equal to the retardation of the pulleys produced by the friction-collars. Thus, any degree of feed can be produced at pleasure by the contrivance of the friction-collars.

1045.

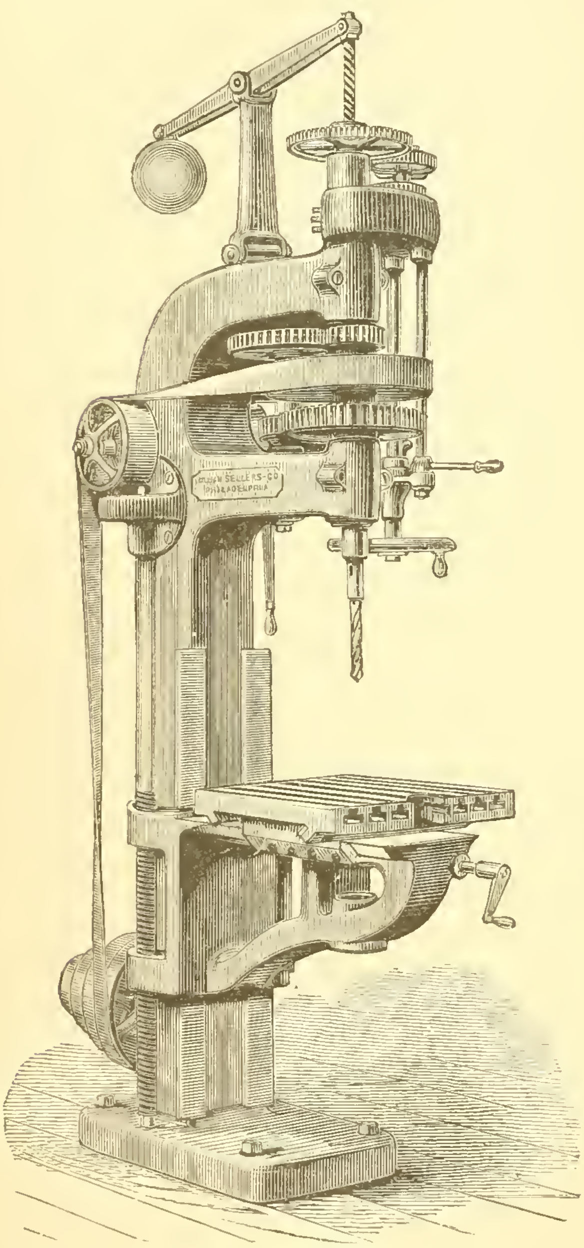
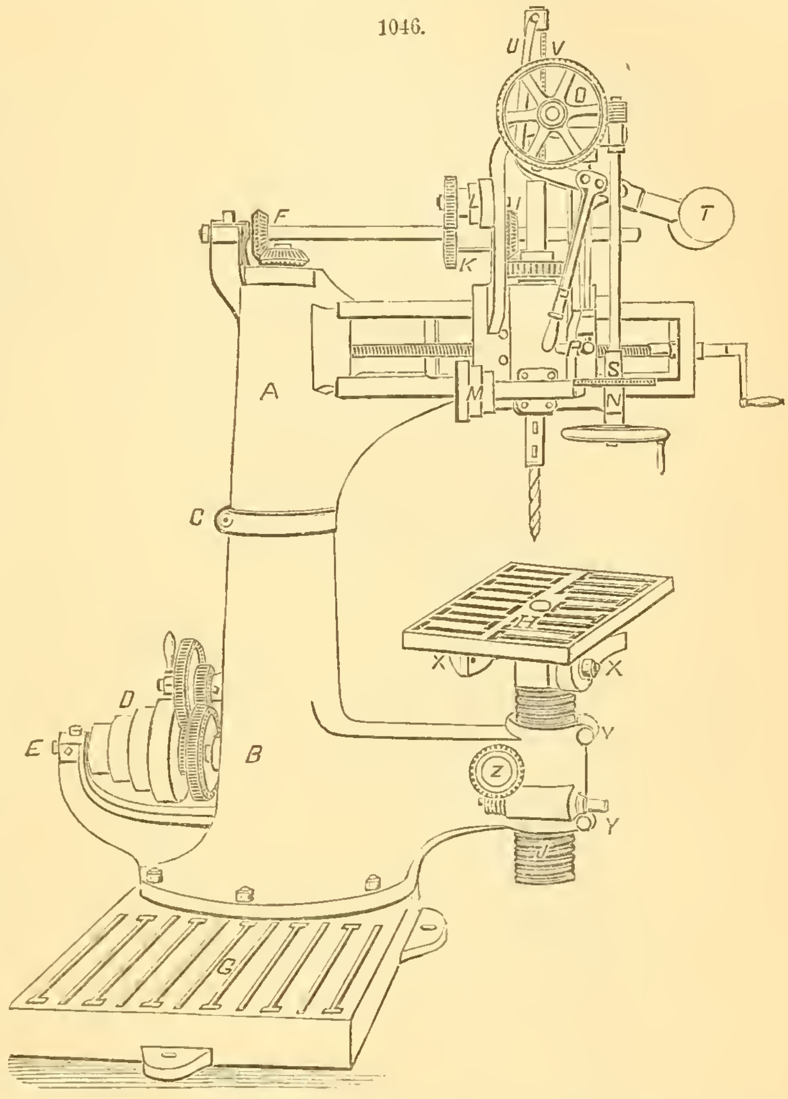


Fig. 1045 represents a patent double-geared vertical drill, made by Messrs. W. Sellers & Co. of Philadelphia. This has a square column and plain or compound tables, to be raised and lowered by a screw operated by power. The table is arranged to swing to one side. The knee-carrying table is provided with a bearing to hold the lower end of the boring bar. The drill-spindle is counterbalanced with quick hand and variable power feed, always in gear, but not interfering with the rapid movement of the spindle vertically by hand. The driving pulley is placed on the spindle, so that when the back-gear is not in use the spindle is driven by a belt only, producing a particularly smooth motion for small drilling. The cone-pulley is at the base of the column, admitting ready change of speed. There is a 45-inch vertical drill, $22\frac{1}{2}$ inches from centre of spindle to face of column, with either plain or compound table. This machine, for holes of $1\frac{1}{2}$ inch and under in cast-iron, has its spindle driven by belt only, but is provided with back-gear to be used for heavier work. In an experiment with small drills, the power feed was used in boring a quarter-inch hole through 3 inches thickness of wrought-iron successfully, and in less time than the same hole was made by a skillful workman feeding by hand.

*Radial Drilling Machines.*—A radial drilling machine by William B. Bement & Son of Philadelphia is illustrated in Fig. 1046. Upon the inner end of the radial arm is formed the sleeve $A$, which is fitted upon the turned upper portion of the column $B$, so as to be rotated at will. It may be tightened by the clamping-bolt $C$, a slot being cut for a few inches at its lower end to admit of the necessary contraction. The cone and gearing at $D$ are of the usual construction, the locking of the cone to its shaft being effected by a sliding clutch within the cone, operated by the projecting knob $E$. A central vertical shaft, provided with suitable bearings in the column $B$, receives motion from the cone-shaft, and transmits it to the upper horizontal shaft through mitre-gears, the upper pair of which is seen at $F$. The connection between the upper horizontal shaft and the drill-spindle will be readily understood from the engraving. The hub of the bevel-gear $I$ is extended through its bearing, and gives vertical movement to the spindle through the spur-gear $K$, cone-pulleys $L$ and $M$, bevel-gears $N$, and worm and worm-wheel $O$; the last carrying a pinion which works in the rack $V$.

The teeth of this rack are cut on the flatted side of a steel cylinder sliding vertically in a suitable bearing. A rod rigidly attached to the spindle passes through its whole length, and has at its upper end a collar and nuts for close vertical adjustment. The worm at *O* is capable of a horizontal movement sufficient to take it out of contact with the wheel; the bearing just below it being arranged to slide, and, as well as the lower bearing *N*, supported in a swivel. This disengaging movement is made by an eccentric at top of the small vertical shaft, which has at bottom the handle *R* within convenient reach of the workman. The bevel-wheel at *N* runs loosely on its vertical shaft, but can be caused to carry it by a sliding clutch *S*, operated by an internal rod ending in a knob below the hand-wheel. The counterweight *T* is cast on the outer end of a lever, the inner end of which is forked and jointed to the two links *U*, one on each side of the spindle; the upper ends of the links being jointed to a small cross-head at top of the rack *V*. By the hand-lever *P* a quick and easy vertical movement can be given to the spindle when the worm *O* is moved out of gear by the handle *R*. When the worm is in gear, a slow vertical movement can be given the spindle by the hand-wheel, while by drawing the clutch *S* into gear the downward feeding movement becomes automatic. The table *H* has positive stops for its horizontal and perpendicular positions, and can be securely held in any intermediate one by the clamping-bolts *X*. By a pinion on the shaft *Z*, working in teeth turned in the stem *J*, it can be raised and lowered. It can also be rotated as desired, and clamped in any position by the bolts *Y*. The planed and slotted base-plate *G* is for holding work too large for the small table.

1046.

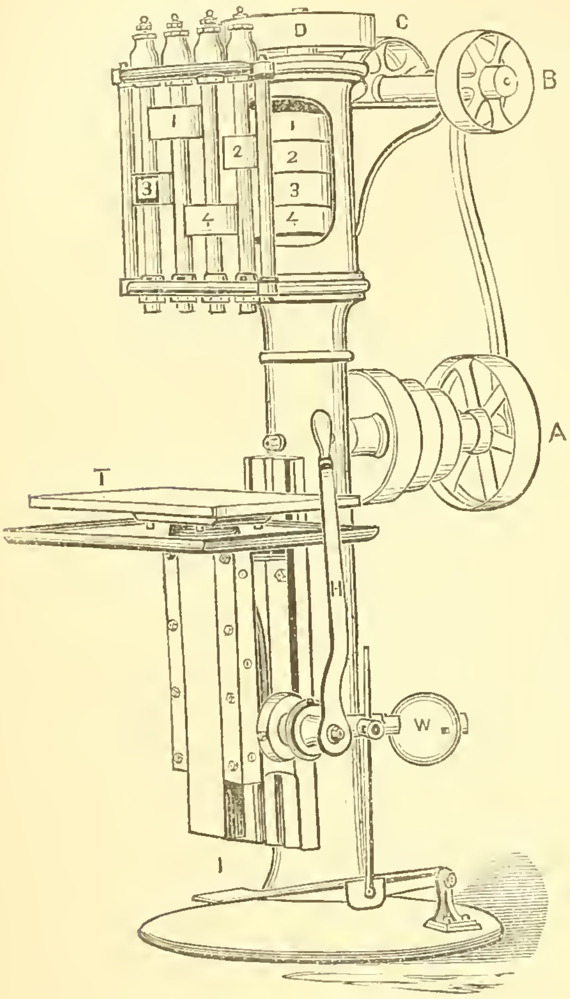



*Multiple Drilling Machines.*—Of this class of machines there are many designs, each adapted to its particular purpose, which may be stated in general terms to be to drill a number of holes simultaneously. In machines employed for heavy work the spindles feed the drill through the work, while for light work it is more convenient to feed the work to the drill, which may be done by a single feeding motion to the table on which the work rests, instead of requiring a feed-motion to each spindle. In the machine shown in Fig. 1047, which is the design of the Pratt & Whitney Company of Hartford, Conn., the driving-spindle stands vertical in the centre of the column, and is belted to the four drill-spindles to drive them, the pulleys on the main spindle being marked from 1 to 4, and the corresponding pulleys on the drill-spindle being similarly marked. By employing belt power, the width apart of the spindles may be varied in case of necessity. The speed of the machine is varied at the cone-pulley, the belt driving the main spindles *D* passing over pulleys *B* and *C* to and around *A*. The table *T* is raised for the feed either by the handle *H* or by the foot-treadle *I*, the weight of the table being counterbalanced by the weight *W*.

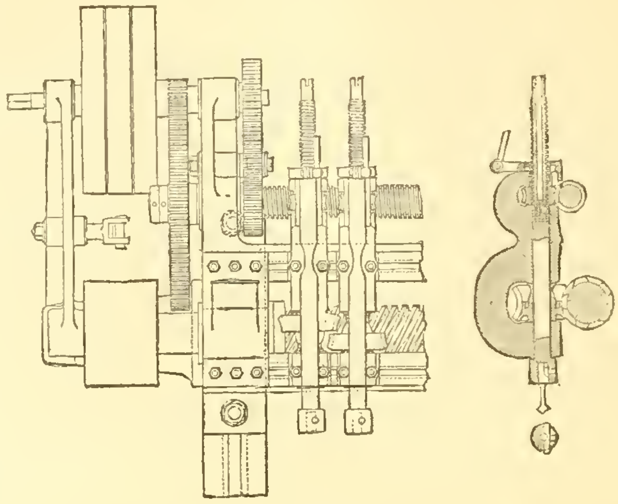
Fig. 1048 represents an improved multiple drill of English construction. In this machine the main driving-shaft is formed of a large steel screw. When more than ten spindles are employed, this screw is cut with a right-hand thread for half its length, and with a left-hand thread for the other half, to neutralize the end thrust. This screw engages with as many worm-pinions as there are spindles to be driven. By keeping these pinions alternately above and below the centre line of the driving-screw, the spindles may be adjusted to a pitch of 3¾ inches, although the pinions are nearly 6 inches in diameter. The adjustment is made by hand, after slacking back the bolts which hold the spindles in place. The pinions have feather-keys taking into grooves on the spindles, which latter are fed up and down by screws working in nuts or worm-wheels, as shown. These worm-wheels are driven by a screw by means of reversible strap motion, which gives a slow feed and a quick return motion. Each screw is fitted at its upper part with a bush (provided with feather-key) encircled by a friction-brake. When this brake is tightened by the handle shown, the screw is prevented from revolving, and is worked up and down by the worm-wheel or nut. When the brake is released, the screw is free to revolve with this nut without rising or sinking; or it may be raised or lowered,

independently of the other spindles, by a removable hand-wheel fitted on a square at its upper end. The lower ends of the spindles are bored out parallel, and the shanks of the drills are turned to an exact fit, this being found to be the best method of insuring the truth of the drills. When this

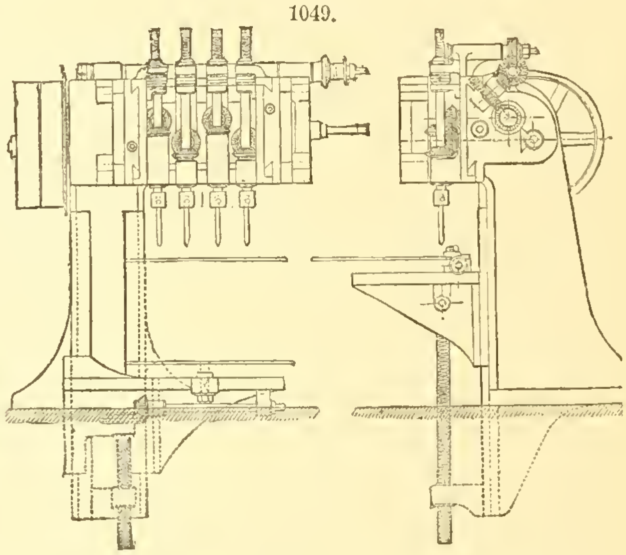
1047.




1048.



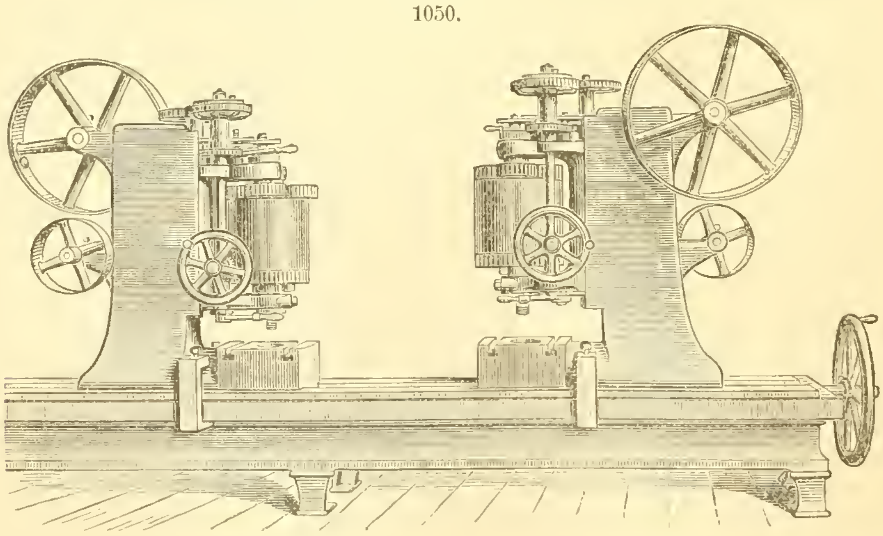
1049.



system is adopted, no templating or centering of the holes is required, as every drill will start its own hole with perfect accuracy. A one-sided cotter passes through the socket, and when driven up tightens on a flat formed on one side of the drill-shank. A drill may thus be removed or inserted without stopping the machine

A four-spindled drilling machine, designed to drill holes in the arc of any circle from 12 inches radius up to a straight line, is represented in Fig. 1049. This machine is of special use for drilling

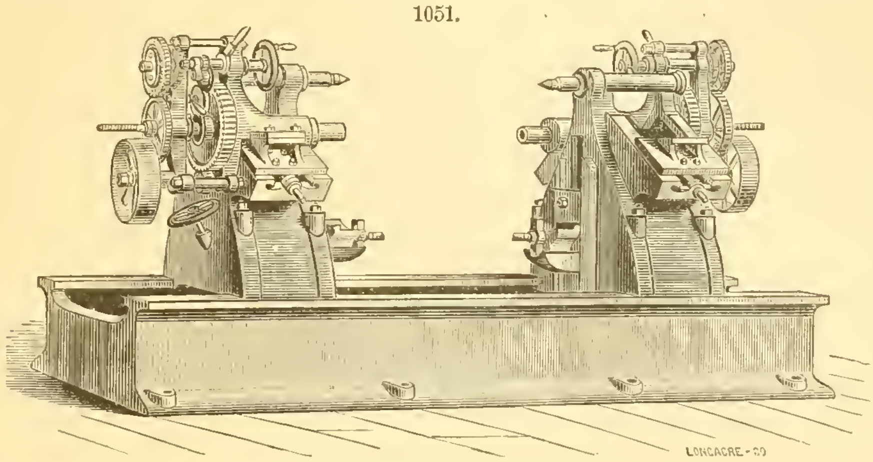
1050.



the flanges of flue-tubes when made with flanged or "Adamson" joints; it will also drill the holes in the edges of boiler-plates before they are bent, either in a straight line or in the arc of a very large circle, such as is required when a boiler is made with "following joints," where each ring of

plates forms the frustum of a cone. The spindles are adjustable from 4 inches to 8 inches apart, and the two outer spindles are adjustable at right angles to the main frame, so that all four will coincide with the desired curve. The work is carried on a rising and falling table, which sinks low enough to admit a cylinder 3 feet in length. There is a slot in the table to admit a stud carrying

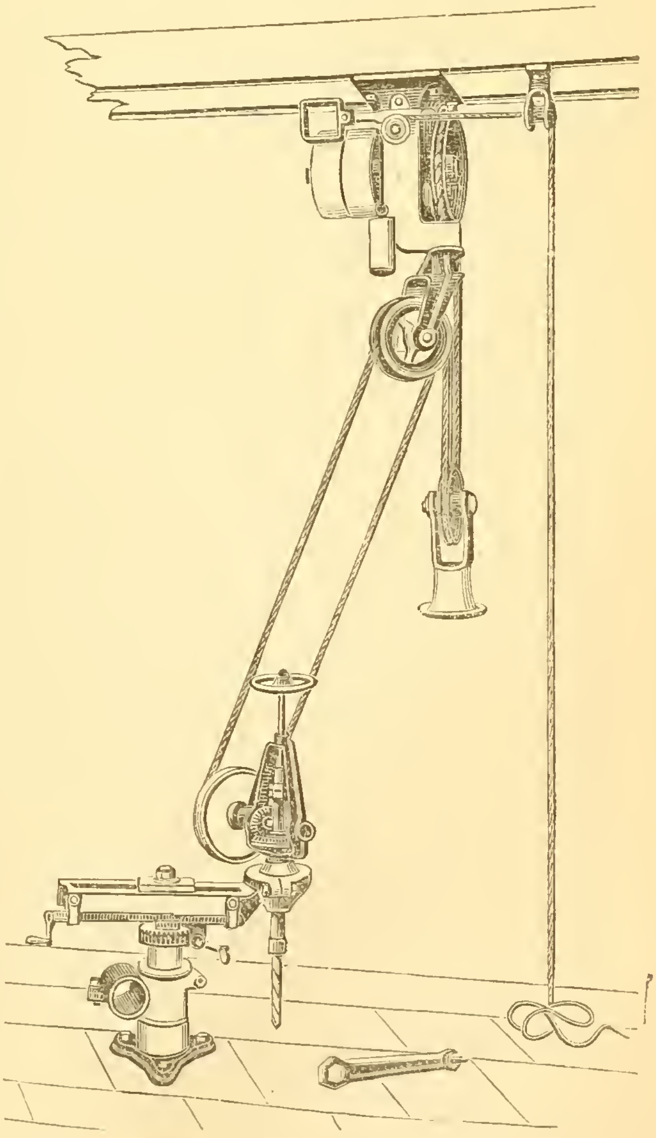
1051.




cross-arms upon which the cylinder or flue section revolves, until drilled all around the flange. For drilling plates a traversing apparatus is fitted to the table, as shown in the end view.

*Traverse Drilling Machine.*—In preparing links for bridge-work, it is advisable, in order to insure accuracy in length, to bore the holes for the pins in both ends at the same time. For this purpose right- and left-hand boring machines are made, sliding on a solid bed, and adjustable to or from each other, to suit the required length of links. The drilling machines, as shown in Fig. 1050, are so placed as to permit the links to be put in place from one side, and, when done, passed out on the other side of the machine. The driving is effected by horizontal belts passing over guide-pulleys, and around a drum on the spindles. The cutters used in this machine are kept cool by water fed to them through the centre of the spindle. In the link-boring machine the two heads are united by bars of wrought-iron, and can slide freely on the cast-iron bed. The expansion of the wrought-iron bars, being the same as the expansion of the link being bored, insures uniformity in the length of the finished work.

1052.



*Horizontal Drills.*—The introduction of small short-stroke engines for mining purposes calling for some ready means of quartering wheels with a crank-throw of only 5 inches, for engines of 10-inch stroke, the horizontal drill (wheel-quartering machine) represented in Fig. 1051 has been constructed by Messrs. W. Sellers & Co., so as to quarter from 5 inches to 13 inches radius of crank, and to bore either for right- or left-hand lead with equal accuracy. The boring-spindles are outside of the wheels, and bore both crank-holes at the same time, each spindle being driven separately and provided with adjustable automatic feed, so as to rough out the holes with fine feed, but finish with a wide feed and light cut. The wheels on their axle are carried by their tread on adjustable shoes, which hold them rigidly in place, while the centres control position of axis only; this insures stability. The machine may be used to advantage as a horizontal drill for other purposes.

*Portable Drilling Machines.*—Fig. 1052 represents Thorne's portable drilling machine, which is especially adapted for drilling all pieces which are inconvenient to move, or which cannot be readily adjusted under stationary drilling machines. It will drill at any angle, in any position, at any distance, and in any direction from the power. The driving apparatus is so arranged that the round belt which drives the machines passes through the centre of a hollow stud, enabling the power to be

taken off in any direction, while the weighted idler keeps the belt tight at whatever distance the machine is worked. The machine is intended to be bolted or clamped by its base to the piece being drilled. It can be adjusted in height by drawing the post out of the socket, and radially by screw and handle on the arm. The arm can be swung in the pillar as a centre by means of a worm and tangent wheel, thus providing delicate adjustments in every direction. The spindle-frame swings in a ball-and-socket bearing to any angle up to 30° from the base, and is also provided with means of fixing it in a vertical position. The whole of the machine, including the post, can be drawn out of the socket, and the post passed into the horizontal hole in the socket for drilling in a direction parallel with the base. The feed-motion is self-acting and variable. (See also the Stow flexible shaft drill, under BITS AND AUGERS.)

*Power Required for Metal-Drilling Machines.*—In drilling machines the power required to remove a given weight of material has been found to be greater than in planing machines. This result is due to the friction of the shavings in the holes, an inference which is especially important when the shavings are tough and the holes small. In fact, in the case of small holes the loss of power from this cause is so large that it has been found that the thickness of the shavings may be left entirely out of consideration, and the formula for calculating the power required be based only upon the diameter of the hole, and two coefficients having values depending upon the material treated. The formula in fact may be of the form $P = a + \frac{B}{d}$, in which $a$ and $B$ are the two coefficients, and $d$ is the diameter of the hole in inches. In the case of drilling machines, Dr. Hartig of Dresden (the results of whose experiments we are quoting) takes, not the weight, but the volume of the material reduced to shavings as the unit of comparison; and, denoting the volume thus reduced in cubic inches per hour by $q$, we derive from his results the following equations applicable to holes from two-fifths of an inch to 2 inches diameter and about 2 inches deep, $P$ being the horse-power required:

$$\text{For cast-iron drilled dry, } P = q\left(0.0168 + \frac{0.00067}{d}\right).$$

$$\text{For wrought-iron drilled with oil, } P = q\left(0.0168 + \frac{0.0269}{d}\right).$$

For drilling machines running empty, it is sufficient to know the number of revolutions per minute of the gearing-shaft $n_1$ and of the drill $n_2$, to enable us to compute the value of $P$ for all varieties of ordinary drilling machines by the following formulæ:

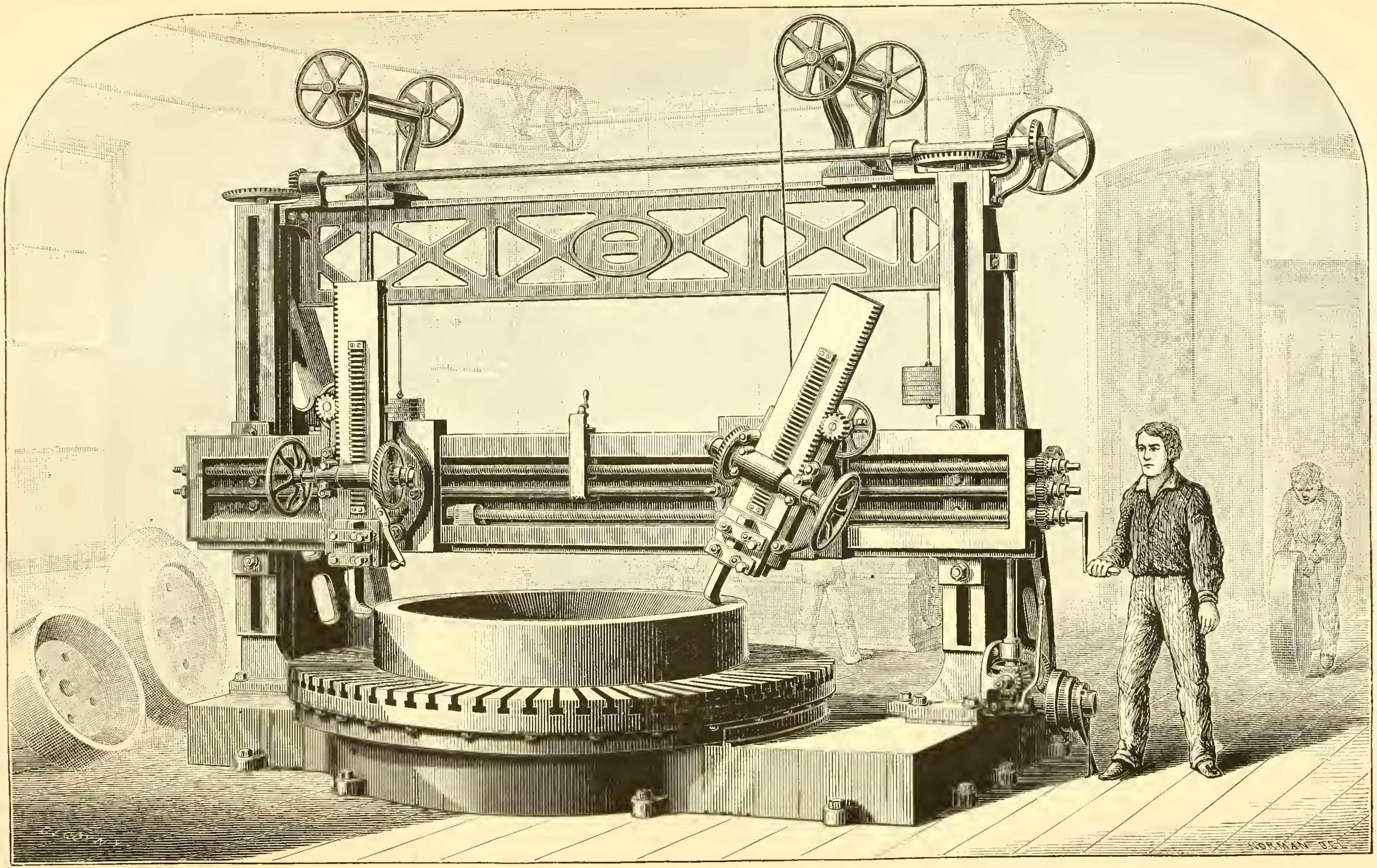
*a.* For drilling machines without gearing, $P = 0.0006n_1 + 0.0005\,n_2$ horse-power.
*b.* For drilling machines with gearing for the drill-spindle, $P = 0.0006n_1 + 0.001n_2$ horse-power.
*c.* For radial drilling machines without intermediate gearing, $P = 0.0006n_1 + 0.004n_2$ horse-power.
*d.* For radial drilling machines with intermediate gearing, $P = 0.04 + 0.0006n_1 + 0.004n_2$ horse-power.

If, for example, we have a machine of the construction $d$, with $n_1 = 120$ and $n_2 = 130$, then $P$ will equal 0.632 horse-power.*

BORING MACHINES. I. FOR METAL.—*Boring*, as distinguished from drilling, consists in turning out annular holes to true dimensions, while the term drilling is applied to perforating or sinking holes in solid material. In boring, tools are guided by axial support independent of the bearing of their edges on the material; while in drilling, the cutting edges are guided and supported mainly from their contact with and bearing on the material drilled. Owing to this difference in the manner of guiding and supporting the cutting edges, and the advantages of an axial support for tools in boring, it becomes an operation by which the most accurate dimensions are attainable, while drilling is a comparatively imperfect operation; yet the ordinary conditions of machine-fitting are such that nearly all small holes can be drilled with sufficient accuracy. Boring may be called internal turning, differing from external turning because of the tools performing the cutting movement, and in the cut being made on concave instead of convex surfaces; otherwise there is a close analogy between the operations of turning and boring. Boring is to some extent performed on lathes, either with boring-bars or by what is termed chuck-boring; in the latter the material is revolved and the tools are stationary.

Boring may be divided into three operations as follows: chuck-boring on lathes; bar-boring when a boring-bar runs on points or centres, and is supported at the ends only; and bar-boring when a bar is supported in and fed through fixed bearings. The principles are different in these operations, each one being applicable to certain kinds of work. A workman who can distinguish between these plans of boring, and can always determine from the nature of a certain work which is the best to adopt, has acquired considerable knowledge of fitting operations. Chuck-boring is employed in three cases: for holes of shallow depth, taper holes, and holes that are screw-threaded. As pieces are overhung in lathe-boring, there is not sufficient rigidity either of the lathe-spindle or of the tools to admit of deep boring. The tools being guided in a straight line, and capable of acting at any angle to the axis of rotation, the facilities for making tapered holes are complete; and as the tools are stationary, and may be instantly adjusted, the same conditions answer for cutting internal screw-threads—an operation corresponding to cutting external screws, except that the cross motions of the tool-slide are reversed. The second plan of boring, by means of a bar mounted on points or centres, is one by which the greatest accuracy is attainable; it is, like chuck-boring, a lathe operation, and one for which no better machine than a lathe has been devised, at least for the smaller kinds of work. It is a problem whether in ordinary machine-fitting there is not a gain by performing all boring in this manner whenever the rigidity of boring-bars is sufficient without auxiliary supports,

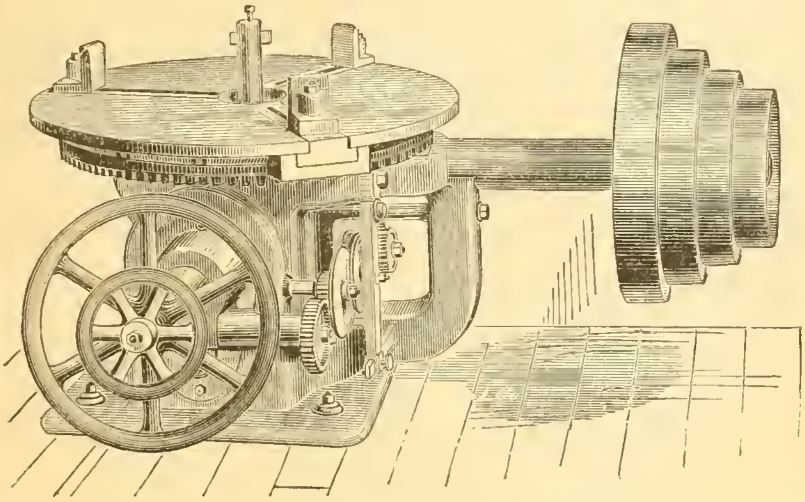
* *Engineering*, xviii., 338 *et seq.*




THE BEMENT BORING-MACHINE.

and when the bars can pass through the work. Machines arranged for this kind of boring can be employed in turning or boring as occasion may require. When a tool is guided by turning on points, the movement is perfect, and the straightness or parallelism of holes bored in this manner is dependent only on the truth of the carriage movement. This plan of boring is employed for small steam-cylinders, cylindrical valve-seats, and in cases where accuracy is essential. The third plan of boring, with bars resting in bearings, is more extensively practised, and has the largest range of adaptation. A feature of this plan of boring is that the form of the boring-bar, or any imperfection in its bearings, is communicated to the work; a want of straightness in the bar makes tapering holes. This, of course, applies to cases where a bar is fed through fixed bearings placed at one or both ends of a hole to be bored. If a boring-bar is bent, or out of truth between its bearings, the diameter of the

1053.

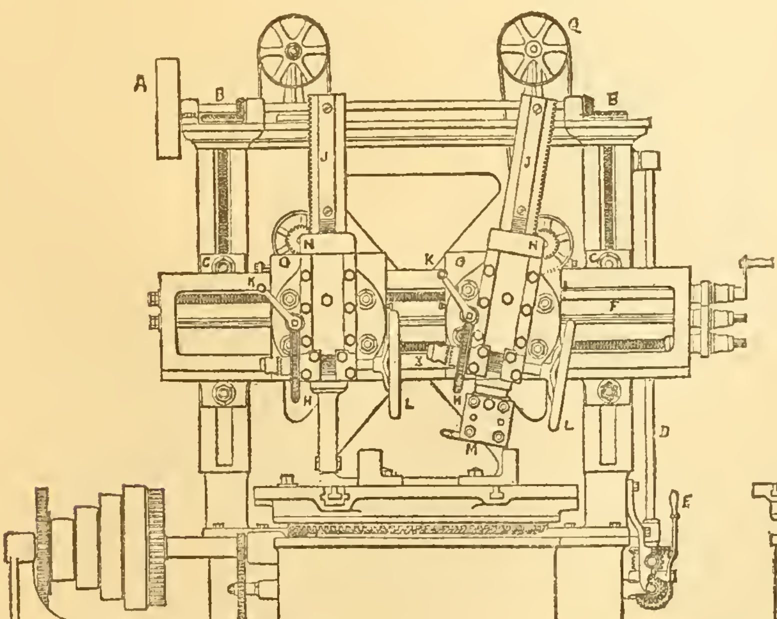


hole, being governed by the extreme sweep of the cutters, is untrue to the same extent; because, as the cutters move along and come nearer to the bearings, the bar runs with more truth, forming a tapering hole diminishing toward the rests or bearings. The same rule applies to some extent in chuck-boring, the form of the lathe-spindle being communicated to holes bored; but lathe-spindles are presumed to be quite perfect compared with boring-bars.*

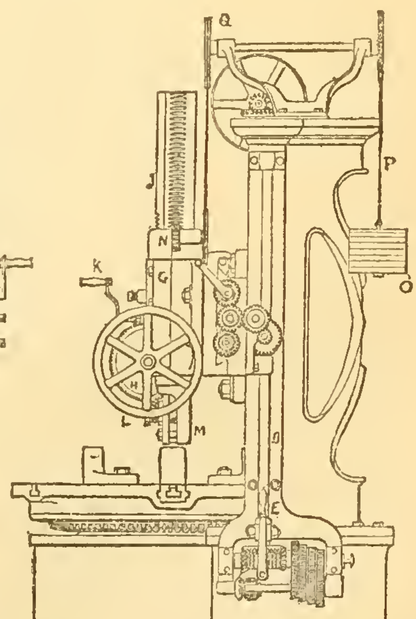
Seller's patent boring mill, represented in Fig. 1053, is a useful tool for boring only. It is adapted to bore car-wheels up to 36 inches in the chuck on the face-plate, and will bore a wheel 6 feet in diameter. It uses boring-bars with double-ended gib-cutters only, the bar being carried by a cross-head below the table.

*Bement's Boring Machine.*—In the full-page illustration and in Figs. 1054 to 1058 is shown a boring and turning machine designed and constructed by Messrs. W. B. Bement & Son of Philadelphia. The

1054.




1055.



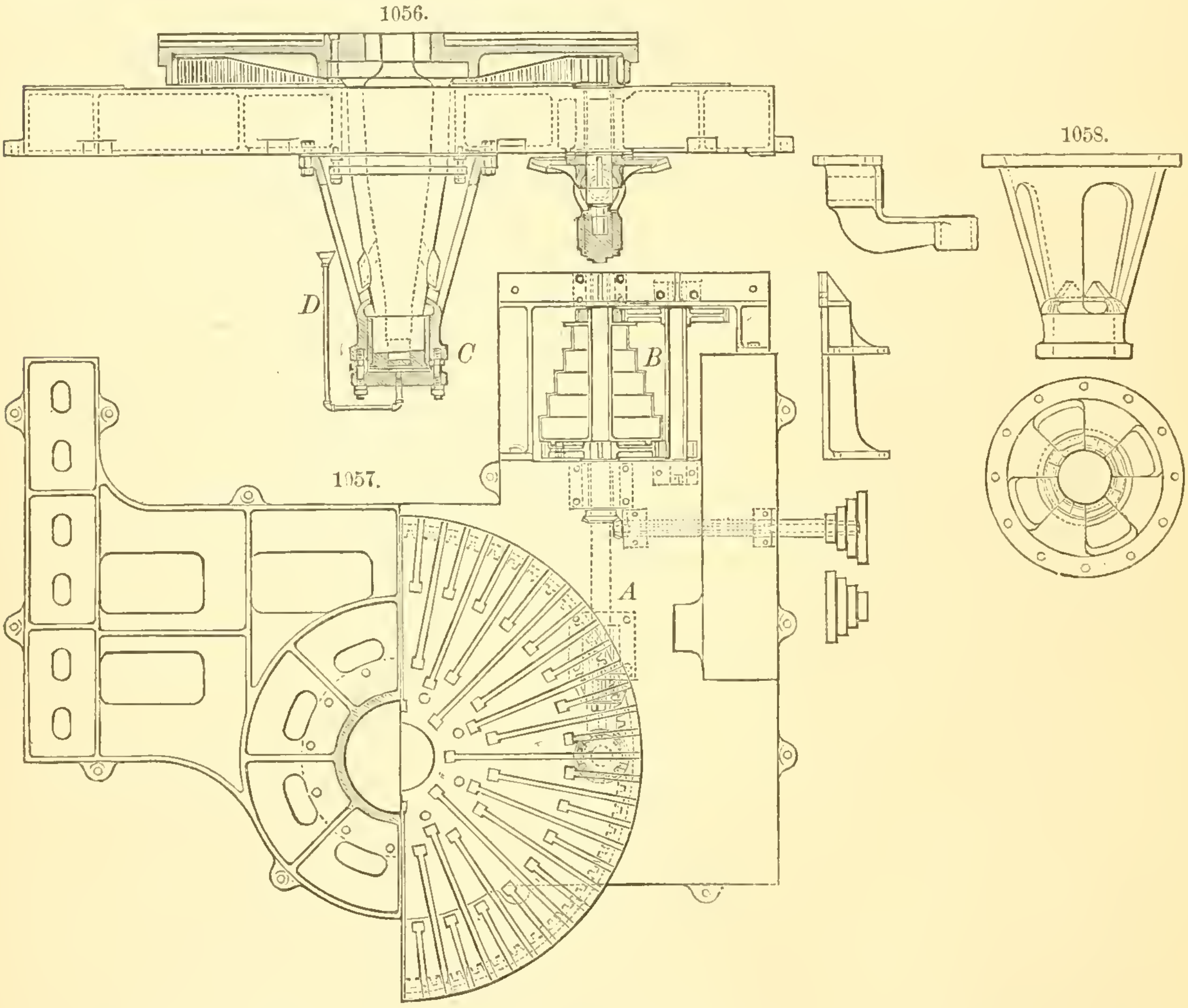

general design of this machine is that of two slide-rests operating upon one cross-slide, supported by uprights similar to those in a planer, the work being chucked upon a horizontally rotating table below. The slide-rests may be set at any desired angle to bore or turn taper or vertical. To perform

* From "Workshop Manipulation," by J. Richards.

those operations parallel, each head may self-act for the feed-motion either parallel or horizontal to the face of the face-plate or chuck-plate, or vertical or at an angle to the same, both slide-rests being employed to either turn or bore simultaneously, or one to turn and the other to bore, according to the requirements of the case. The face-plate being near to the ground facilitates the handling of the work to chuck it; and the plane of the face-plate being horizontal also assists that operation; while the bed-plate or framing supporting the table is from its compactness necessarily very rigid.

The details relating to the driving-gear, spindle, and face-plate will be best seen in the elevation, Fig. 1056, and plan, Fig. 1057, each of which is partially in section. The shaft *A* is driven by a cone-pulley and back-gearing *B*, of the usual construction, through bevel-gears and a pinion, the latter actuating an internal spur-wheel, which is bolted to the face-plate. It also, by means of bevel-gears and cone-pulleys, gives motion to the feeding apparatus shown in Fig. 1054. The attachment of the face-plate to the spindle is assisted by a broad flange and eight tightly-fitted bolts. The bushing is fitted externally to the cylindrical opening bored in the centre of the bed-plate, and internally to the conical bearing of the spindle, on which it is adjusted by bolts. The housing is rigidly bolted to the bottom of the bed-plate, and is bored at its lower end to receive the step-bearing, which is adjusted vertically by suitable bolts. The step *C*, which carries the entire revolving weight, consists of two heavy disks, composed of a hard alloy of copper and tin, between which disks is inter-

1056.



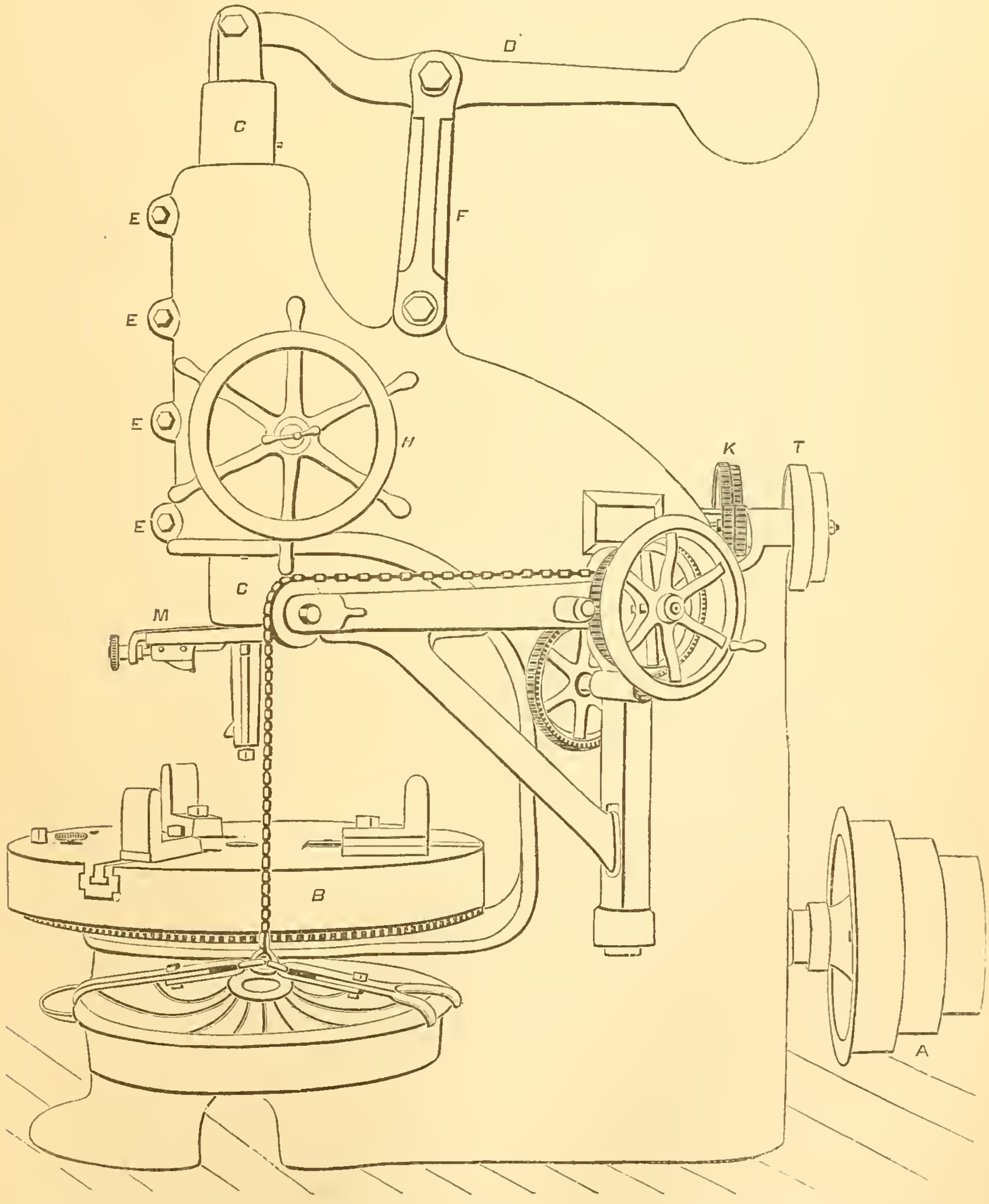

1057.

1058.

posed a third one of steel hardened and afterward ground true. The upper disk is caused to revolve with the spindle, and the lower one to remain stationary, the intermediate steel one being left entirely free. The wearing surfaces of the bronze disks and the cylindrical surface of the spindle-bearing have suitable grooves for distributing the lubricating oil, which is supplied through the pipe *D*. Such borings, etc., as may find their way into the interior of the spindle, are discharged clear of the bearing by the openings over the inclined guards, and the lower end of the spindle is closed by a plug, Fig. 1058. The bed-plate is hollow and internally ribbed, as shown in the sectional part of Fig. 1056, having the necessary openings in the bottom for the support of the cores required to mould the same. Raised facings are planed to receive the uprights which carry the cross-slide. An independent countershaft, having a backward and forward motion, drives the pulley *A*, Fig. 1054, and, through the bevel-gearing *B B*, the vertical screws in the hollow front portions of the uprights by which the cross-slide is heightened and lowered at will, the nuts *C C* serving to secure it when brought to the required position. On the inner end of the cone 3 is a worm driving the worm-wheel. On the shaft of the latter are two opposite bevel-pinions, both of which mesh with the bevel-wheel at the foot of the vertical splined shaft *D*. Both of these pinions are loose upon their shafts or bearings, but either can be engaged by a clutch operated by the lever *E*; and since the revolutions of these pinions are in opposite directions, it follows that the shaft *D* will revolve in opposite directions according to which of the pinions is engaged by the clutch.

At the right of the cross-slide are shown three pinions, the middle one of which (and through it the other two) is driven by a spur-wheel, which receives motion from the splined shaft $F$ through the medium of bevel-gearing not shown, but which is carried in a frame bolted to the back of the cross-slide. These pinions are also loose or free upon their respective shafts, but each is furnished with a clutch, the lower and upper ones when engaged respectively actuating the screws for the horizontal movement to the right or left for the tools, while the middle one when engaged actuates the splined shaft $F$, which gives the vertical or angular motion to both tools. In the saddles $G$, which move longitudinally on the cross-slide, are fitted the swivel-slides $J$ $J$, each secured in any vertical or angular position by six bolts, the heads of which are in an annular T-groove provided in the saddle. In the rear of each saddle is an arrangement of bevel-gears and clutch precisely similar to that described as connected at the foot of the vertical splined shaft $D$. By it is transmitted a reversible motion from the horizontal splined shaft $P$ to the projecting worm-shaft; and the worm-shaft $H$ when engaged by the clutch $I$ actuates a pinion meshing in a steel rack inserted in the tool-slide $J$. It will be seen then that while one of the rests is feeding the tool either vertically, at an angle, upward, or downward, the other rest may feed its tool in any direction. A crank $K$ applied to the outer end of the worm-shaft enables the operator to feed the tool-slide at any required rate by

1059.




hand, and when the clutch $I$ is disengaged a rapid feed may be imparted by the hand-wheel $L$. The cutting tool is held upon a hardened plate (secured to the front of the tool-slide at its lower end) by the clamps $M$, which are so arranged that the tool-point may be adjusted in any position to suit the

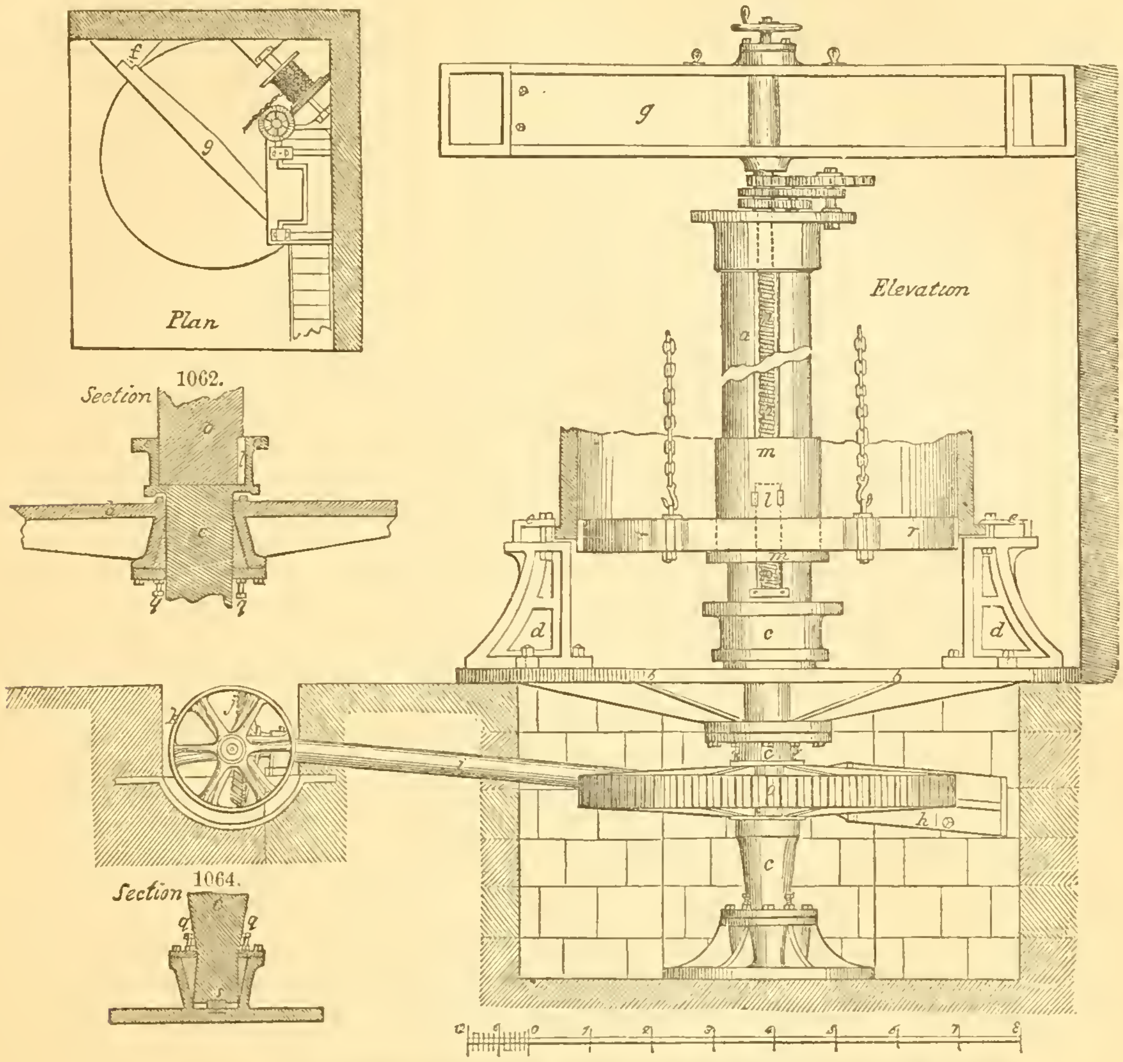
location of the duty. The tool-slide has sufficient length and rigidity to carry a cut nearly 3 feet below the level of the cross-slide, and hence its weight is sufficient to require a counterbalance capable of acting upon it efficiently in all its positions. For this purpose teeth are cut in one of its sides, forming a rack in which meshes the pinion *N*, the connection between the latter and the weight *O* being made through wire ropes. Each of the wheels *Q* and *U* is grooved spirally on its circumference to receive the wire rope, and is of sufficient width to receive the greatest requisite quantity without overlapping. Each of the weights *O* consists of a number of separate pieces readily removable, so that the weight may be varied as required, less being needed as the tool-slides are inclined from the perpendicular.

*Car-Wheel Boring Machine.*—Fig. 1059 represents a car-wheel boring machine constructed by the Putnam Machine Company of Fitchburg, Mass. *A* is the driving cone-pulley, the spindle to which it is attached having bearings provided in the frame. At the end of this spindle is a pinion gearing into the teeth shown beneath the table *B*, and by this means the table is caused to revolve. *C C* is the boring-bar, which is counterbalanced by the weighted lever *D*. The bearing of the bar *C C* at that part of the frame through which it passes is made adjustable to fit the bar by the following means: The front of the bearing is split along its entire length, and on each side of the slit are the lugs shown at *E E E E*. Through these lugs pass bolts with nuts, so that by screwing up the latter the bearing is closed to fit the spindle or boring-bar to the requisite degree. To afford a tension upon the adjustment, and thus prevent the nuts from becoming unset, a piece of wood is inserted into the slit referred to, and against the resistance of the wood to compression, as well as of the iron to being sprung, the nuts are tightened. By this means a delicate adjustment is readily obtained. The link or bar *F* is pivoted at each end to permit of a vertical motion to the bar *C C*. A vertical movement by hand may be given the bar *C C* by means of a rack upon its back, geared with a pinion attached to the shaft to which the hand-wheel *H* is secured. Self-acting feed is given to the bar by a spindle to which the gears *K* are attached, and which is connected by a worm and wheel movement to the pinion working in the rack at the back of the bar. *M* is an attachment containing a slide and tool-post for the purpose of facing off the surfaces of the hubs. To enable the machine to bore a taper hole, the following device is resorted to: The table *B* is composed of two disks bolted together, the face of one of which is beveled slightly toward the outer edge. By adjusting the bolts so that the beveled part of the face comes in contact with the other disk, the table is thrown out of horizontal level, and hence a taper hole is bored. In order to prevent spring and insure steadiness in the table when thus set, two screws pass through the elevated side of the upper table, their ends coming in contact with the face of the lower one. The machine is provided with a crane to lift the work, as shown.

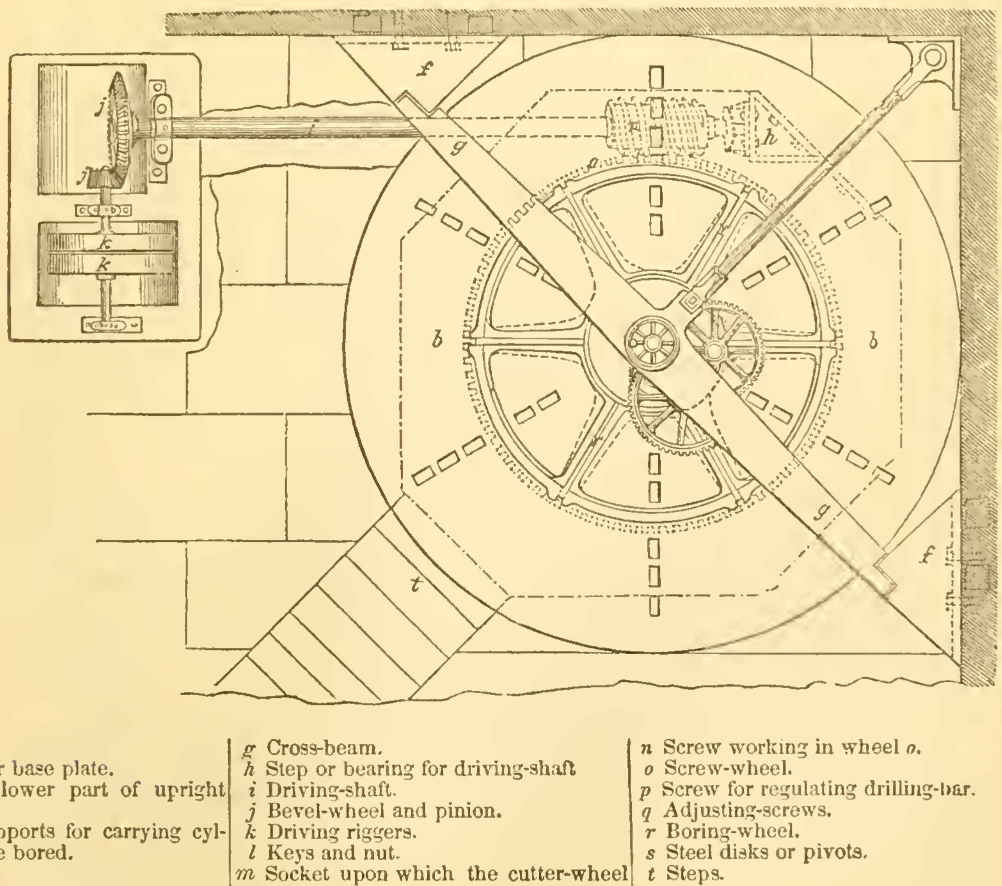
Fig. 1060 represents a cross-section of Nasmyth's cylinder-boring machine, and Fig. 1063 a plan showing its position in a corner of the building where it is placed. In these two views it will be seen that the driving part of the machinery is situated below the ground-line on suitably strong foundations, in which it is inclosed. These parts are rendered accessible by the steps *t*, which are found to be necessary in cases where the machinery is likely to get out of order, a precaution never to be neglected. The two riggers *k k* receive their motion from the main shaft by means of a leather strap: one of these runs loose on the shaft, and the strap is thrown on it when the machine is not at work; this is done at pleasure with the greatest possible facility; by a bevel-wheel and pinion *j*, it is then conveyed through the shaft *i* to the endless worm *n*, working in a large worm-wheel *o*, which is fixed on the great vertical boring-bar *a*, whereby a very easy motion is obtained, and all jerks are avoided. It will be seen by the series of wheels in Fig. 1063 how much the speed of the boring-bar is reduced. The shaft *i* is placed at an angle, and works in a bearing or plumber-block and a step *h*, both of these being made of brass. The vertical bar is made in two parts, *a* and *c*, the upper one *a* for carrying the cutter-head or boring-wheel *r*, while to the lower one is connected the driving apparatus. They are coupled together by the upper one resting, as is shown in Fig. 1062, in a socket on the top of the lower one; a steel key *l* is then driven in, which entirely prevents it from turning. The toe of the bar *c* rests in a step or socket shown in Fig. 1060; the entire weight of this bar and its appendages is thrown on the hardened cast-steel disks *s*, which are constantly kept supplied with oil. Both extremities of the bar *c* are rendered adjustable to the greatest possible accuracy by means of the small set-screws *q q*, Figs. 1062 and 1064, which, by being tightened, press against the conical brass segments, the upper one forming part of the great base or floor-plate *b*, which is materially strengthened by six strong ribs on its under side. The cross-beam *g* is well fitted to the sockets *f*, built into the wall of the building, where they are bolted by strong bolts. In the boring-bar *a* is a deep socket *m*, Fig. 1060, which allows the bar to slide up and down by means of the screw *p* and the nut *l*; upon the lower side of this socket is a flange *m*, upon which the cutter-head or wheel *r* rests, receiving its motion from the bar by means of a nut, answering both the purpose of nut and key. By the different arrangements of the sun-and-planet motion of the wheels on the upper part of the bar, any degree of motion can be given to the screw for the descent of the cutter-wheel. After the cylinder has been once bored through, the cutter-wheel is raised by means of a small crane and the chains, Fig. 1061; and by the peculiar arrangement of the nut *l* in the socket *m*, the cutter-wheel can be drawn up the cylinder without turning the screw *p*, as it leaves the nut behind, which is afterward screwed up, there being no other weight to raise but that of the nut. The cutters are then set afresh to the new or finishing cut, after which the cylinder may be considered perfectly true.

The machine represented by Fig. 1065 is, with few exceptions, the same as that last described, designed for boring the cylinder in a vertical position, whereby numerous advantages are obtained. The motion is communicated by the driving-pulley *c* to a bevel-pinion working the bevel-wheel *d*; the shaft on which this wheel is fixed has on its opposite end a worm for communicating the motion through the worm-wheel to the upright shaft *f* and boring-bar *a*, having on its circumference the grooves *a'* in which the cutter-head is movable, sliding up and down according to the progress of the

1061. 1060. 1062. 1064.



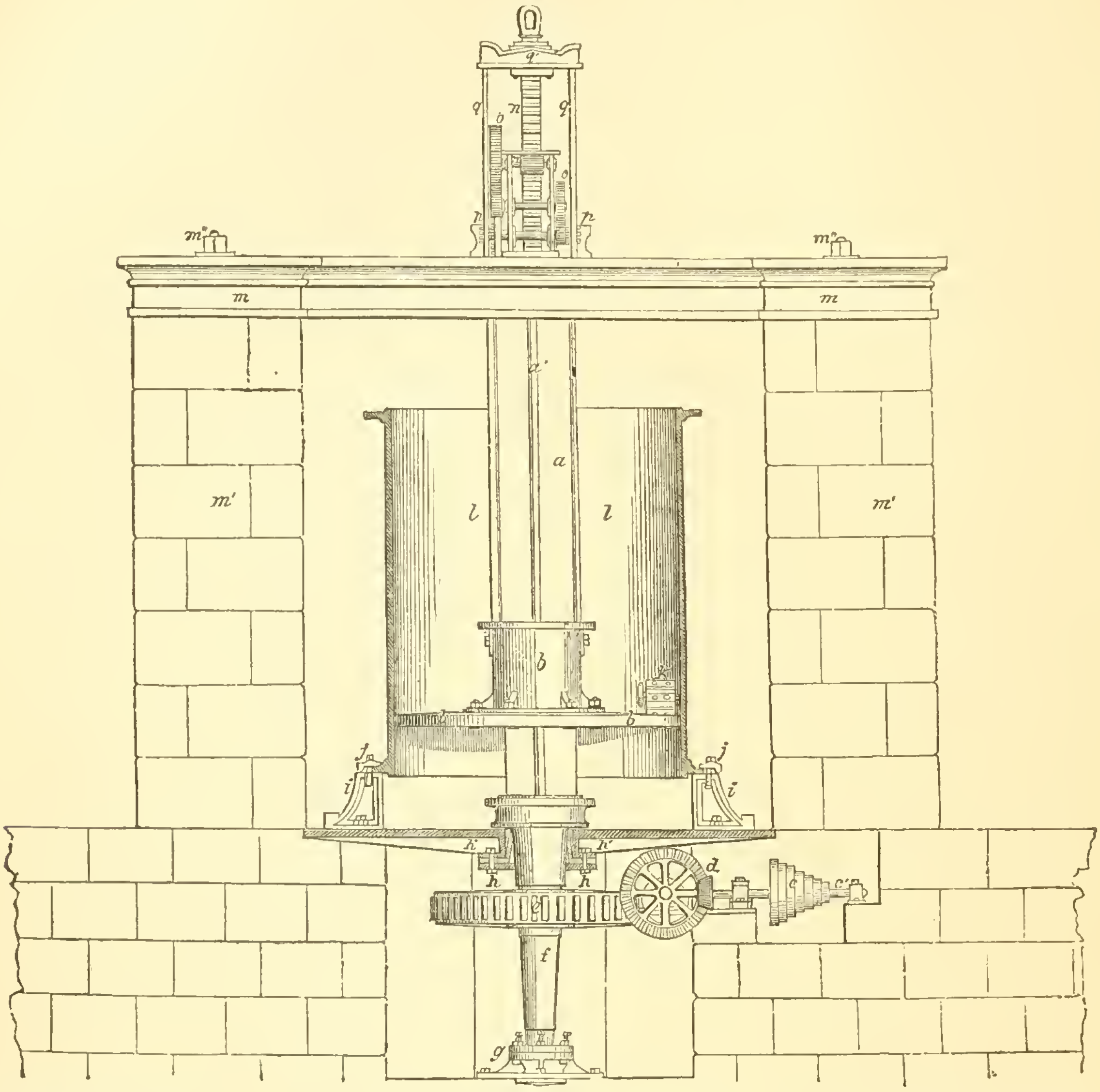

1063.



*a* Boring-bar.
*b* Foundation or base plate.
*c* Socket and lower part of upright bar.
*d* Movable supports for carrying cylinder to be bored.
*e* Clamps.
*f* Socket for carrying the beam *g*.
*g* Cross-beam.
*h* Step or bearing for driving-shaft
*i* Driving-shaft.
*j* Bevel-wheel and pinion.
*k* Driving riggers.
*l* Keys and nut.
*m* Socket upon which the cutter-wheel rests.
*n* Screw working in wheel *o*.
*o* Screw-wheel.
*p* Screw for regulating drilling-bar.
*q* Adjusting-screws.
*r* Boring-wheel.
*s* Steel disks or pivots.
*t* Steps.
*u* Tie bar.

work; $k$ is a tool-carrier fixed to the cutter-head. The foundation plate $h$ forms a bearing for the upright shaft, the lower end of which rests in the step $g$, while the cylinder $l$ is secured by the clamps $j\ j$ to the supports $i\ i$ fixed to the foundation plate. These parts are in every respect similar to the

1065.



*a* Upright boring-bar.
*b* Cutter-head working up and down in the three V's $a'$.
*c* Driving-pulleys fixed on shaft $c'$.
*d* Bevel-wheel and pinion for conveying the motion at right angles.
*e* Worm-wheel.
*f* Upright shaft for working boring-bar.
*g* step for shaft.
*h* Foundation plate and boring-box bearing tightened by conical pieces and screws $h$.
*i* Supports for carrying the cylinder to be bored.
*j* Clamps for fixing cylinder to supports $i$.
*k* Tool-carrier fixed to cutter-head.
*l* Cylinder being bored.
*m* Entablature for guiding the upper part of bar, bolted to walls $m'$ by bolts $m''$.
*n* Rack and pinion for raising the cutter-head, worked by spur-wheels and pinions $o$.
*o* Spur-wheels and pinions.
*p* Internal screw-wheel on the upper part of cutter-head conveying the self-acting raising motion to it, by the trullion-wheel and spur-wheels and pinions $o$.
*q* Side-slings which convey the elevating or cut-feeding motion from the rack $n$ down to the cutter-head $b$. All revolves with the boring-bar except the internal screw-wheel or screwed hoop $p$, which is stationary, being bolted to the entablature.

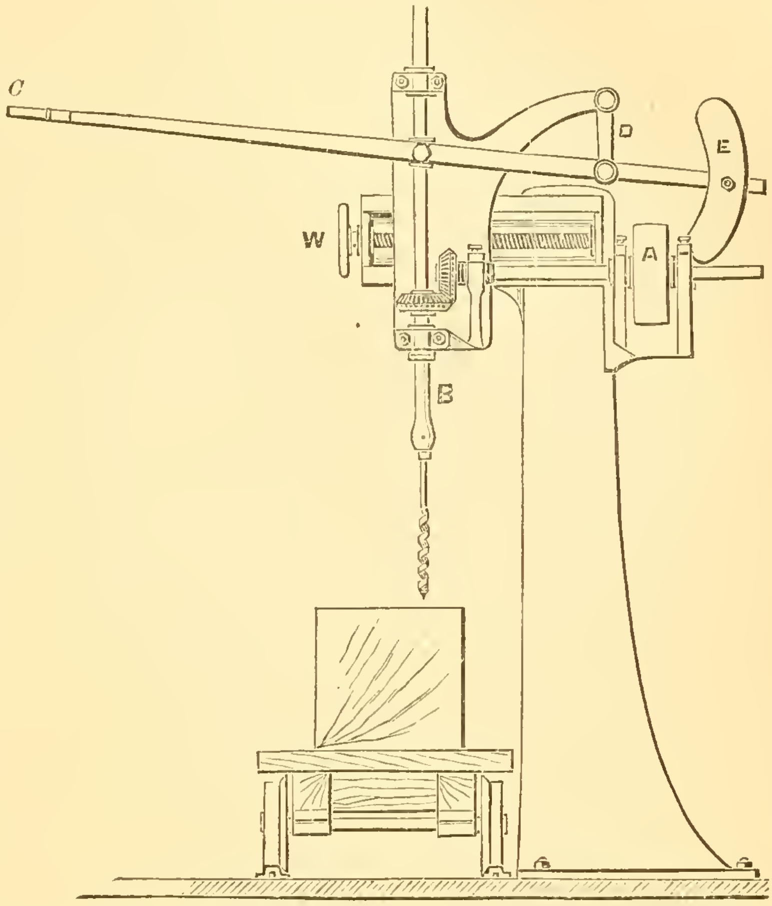
boring machine shown in Fig. 1060, by which they are more fully described. Two strong piers of masonry $m'$ support the entablature $m$ (for carrying the self-acting apparatus for raising and lowering the cutter-head $b$), to which it is bolted by strong holding-down bolts $m''$. This apparatus consists of a rack $n$ worked by a pinion, the motion being transmitted from a trullion-wheel through two spur-wheels and pinions $o$. The whole of this upper machinery revolves with the boring-bar, with the exception of the internal wheel or screwed hoop $p$; the consequence of which is, the small trullion-wheel is made to turn on its axis by the thread of the wheel $p$ in which it works, and thereby ultimately raises the cutter-head $b$, the two side-slings connecting it to the upper frame $q'$, to which is fixed the rack $n$. This machine was made for the purpose of boring large cylinders, 10 feet in diameter.

For boring in the lathe, and for power required for boring machinery, see LATHE.

II. FOR WOOD.—*Boring Machines.*—The distinction previously noted between boring and drilling is not followed with reference to this class of wood-working machines, the operation being always termed boring. In the designing and arrangement of such machines, the main object to be observed is adjustment of the material or of the augers so that they can be brought to different positions with the least expenditure of time and effort. To consider the matter in a general way, we will assume that a compound movement is required, transverse to and longitudinally with the timber.

The longitudinal movement, being of long and indefinite range, is best accomplished by moving the material; the transverse movement, on the contrary, being short and less used, is best accomplished by a lateral adjustment of the spindle. The longitudinal adjustment, having to carry the weight of the material, must be accomplished for the heavier class of work by mechanism that will increase the power of the operator and diminish the motion so as to secure accurate adjustment. The lateral adjustment of the boring tools should also be done by hand, as no special power is needed to perform it. For machines that are arranged to bore holes on one line only, the lateral motion of the spindle becomes simply an adjustment, as distinguished from a continuous movement at will. The spindle or table, when "set," remains fixed during the time of boring the holes in one line.* Boring machines to operate screw-bits should run at from 1,000 to 2,000 revolutions per minute, according to the kind of wood or the size of the bits used.

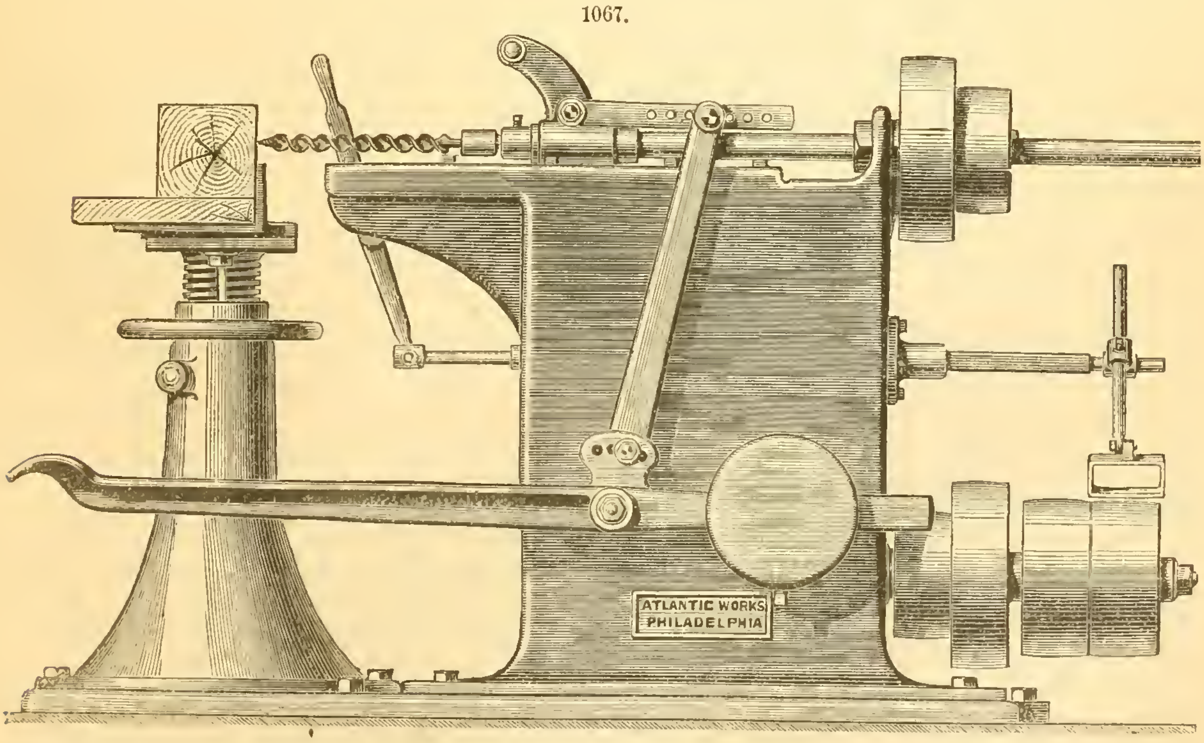
1066.




In Fig. 1066 is shown a wood-boring machine of English construction. *A* is the driving-pulley, which rotates the auger-spindle *B* by means of the bevel-gears. The spindle is fed by hand by depressing the lever *C*, the link *D* being provided to afford a true vertical motion to the spindle. *E* is a weight to counterbalance the weight of the handle *C*. The head carrying the spindle and hand-lever traverses the slide shown by operating the hand-wheel *W*. The table supporting the work travels upon the wheels, to facilitate the movement and adjustment of the work.

The horizontal boring machine shown in Fig. 1067 is of American design. The spindle *A* passes

1067.




and slides through the driving-pulley *B*. The forward spindle-bearing *C* traverses in a guide-slot provided in the frame, and thus follows the movement of the spindle, affording it at all times equal

* J. Richards's "Wood-working Machines."

bearing support. The spindle-feed is obtained by depressing the lever $D$, which operates the arm, the latter being attached to the link $F$, which is pivoted at the end to the bearing $C$. The table is adjustable for height by means of the hand-wheel $W$, which acts as a nut upon the table-spindle, the latter having a feather-way to prevent its rotating with the wheel. The spindle has two speeds, as shown by the stepped pulleys. The gauge $G$ can be placed before or behind the work, as circumstances may render most desirable.

1068.

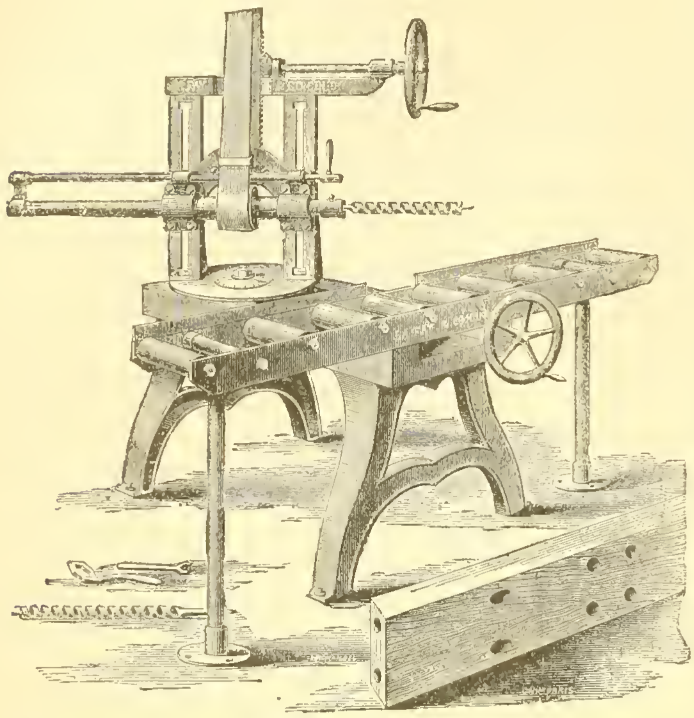


Fig. 1068 represents a radial horizontal car-boring machine, designed by J. A. Fay & Co. particularly for car and bridge work, and for straight, angle, and end boring. It is well known in car shops that the holes in truck and body bolsters for the truss-rods are among the most difficult to be bored. This machine will bore straight or angle holes without moving the timber, all the necessary adjustments being made with the head and spindle carriage. The boring-spindle has a horizontal movement of 24 inches, allowing holes to be bored to that depth. The head or carriage has a horizontal movement in planed sides in the frame, which permits it to be brought close up to the stuff when doing angle-work. The head is raised and lowered by a hand-wheel, geared to a screw of coarse pitch, by which means the auger is brought to the exact point desired without changing the position of the timber. The belt is kept at the proper tension by means of a weighted pulley hung in a slack loop of the belt, which allows the boring-arbor to be moved either up or down, or to any angle desired.

*Power Required for Wood-boring Machines.*—In drilling timber with holes from two-fifths of an inch to 4 inches diameter, and of depths up to 6 inches, Dr. Hartig's experiments give the following values for $P$ (power required), the symbol $d$ representing diameter of hole in inches, and $q$ denoting the volume of material reduced to shavings in cubic inches per hour:

$$\text{For drilling pine, } P = q\left(0.000125 + \frac{.000656}{d}\right).$$

$$\text{For drilling alder, } P = q\left(0.000472 + \frac{.001423}{d}\right).$$

$$\text{For drilling white beech, } P = q\left(0.003442 + \frac{.001495}{d}\right).$$

For example, if we suppose the case of a machine employed in drilling 2-inch holes in white beech, and suppose 1,220 cubic inches of timber to be drilled away per hour, then the value of $P$ will

$$= 1220\left(0.003442 + \frac{.001495}{2}\right) = 1220 \times 0.0041895 = 5.11 \text{ H.P.}$$

If, then, such a machine requires 0.22 horse-power to drive it when empty, the total driving power required when doing the above work will be 5.11 + .22 = 5.33 horse-power. Dr. Hartig gives this example as illustrating the mistake frequently made in estimating the power required to drive tools; it being, as he remarks, not uncommon to find about 1½ horse-power allowed for driving a wood-boring machine of the size above dealt with, while at the same time a large and heavy planing machine for iron will be allowed perhaps 5 horse-power, although in the latter case it is but rarely that more than 1 horse-power will be necessary.* J. R. (in part).

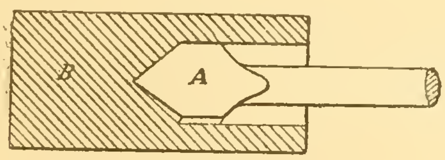
DRILLS, GRAIN. See Agricultural Machinery.

DRILLS, METAL-BORING. A drill is, all things considered, the most effective tool employed by the machinist; for, while its cutting edges are necessarily of decidedly undesirable angles and form, it sustains the very roughest of usage, and yet will bear more strain in proportion to its strength than any other cutting tool. The reason of this is that it is supported by the metal upon which it is operating, and is thus prevented from springing away from its duty. This support may be of two kinds: first, that due to the wedge shape of the main cutting edges, one to the other; and second, that to be derived from making the diameter of the drill parallel for some little distance behind the cutting edges, so that the sides of the drill, by contact with the sides of the hole, serve to guide and support the tool. The latter, however, only comes into operation at and after such time as the drill has entered the metal sufficiently deep to form a recess of the full diameter of the drill. The support given to the drill, in the instance first cited, arises from the tendency of either of the cutting edges to spring away from the cut, which is, of course, counterbalanced by the opposite cutting edge having the same tendency, but in an opposite direction, so that between the

* See *Engineering*, xviii., 338 *et seq.*

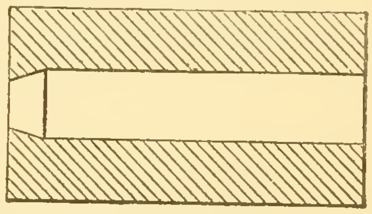
two the drill is held to a central position; and also from the tendency of the drill-point to force itself forward (by reason of the pressure behind it) as far into the cone formed by the end of the hole as possible, as the end of the hole and the cutting end of the drill are two cones, one being forced into the other. In a drill properly ground (that is, having its cutting edges at an equal angle to the centre line of the length of the drill, and of an equal length from the centre of the drill or point of junction of the cutting edges), both the cutting edges and the sides of the drill act as supports and guides, tending to sustain it under the strain and keep it true. If, however, the drill is not ground true, the strain upon it becomes very great, because the whole force of the cut is then placed upon one cutting edge only, and is continuously tending to thrust the point of the drill outward from the centre of the hole being drilled, hence forming a hole larger in diameter than the cutting part of the drill—that is to say, a hole whose diameter will be twice that of the radius of the longest cutting edge of the drill, measured from the centre line of the length of the drill. If, under such conditions, one side of the drill bears against the sides of the hole, as shown in Fig. 1069, *B* being the metal and *A* the drill, there will be created two opposing forces, independent of the strain necessary to sever the metal: one being the endeavor of the point of the drill to keep to the centre of the hole, because of the conical shape of the end of the hole and point of the drill; and the other being the endeavor of the cutting edge to force the drill to one side and the point of the drill out of the centre of the hole. And as the pressure of the side of the drill against the side of the hole will tend to force the drill to revolve true with that side of the drill, so that the point of the drill will revolve in a circle and not upon its own axis, the result will be a hole neither round, straight, nor of any definite diameter, as compared to the diameter of the drill. Drills that are a trifle too small for the required size are sometimes purposely ground a little out of true, so as to cause the hole to be larger than the drill; but the action of such drills is distorted, and it is impossible to estimate exactly how much deviation is necessary to the required increase of diameter of the hole. Part of the power driving the drill is lost, the loss being due to the presence of the above opposing forces; and the drilling operation is slow by reason of only one edge of the drill performing any cutting. Hence, the feed of the drill being only half as rapid as it should be, it is an

1069.




1070.

A



unmechanical expedient and a loss of time, especially if the hole is to be drilled clear through the metal; for in that case, as soon as the point of the drill emerges through the metal, and is therefore released from its influence, the cutting edges will gradually adjust themselves to the hole, and form the remainder of the hole to the size of the diameter of the drill, the hole, when finished, appearing as in Fig. 1070. Thus the end *A* of the hole will require to be filed out, entailing in all more loss of time than would be required to make a drill of the proper diameter.

The importance, then, of taking especial pains to grind a drill true being apparent, we may next consider how thick the point of the drill should be. It is here that the main defect of the drill as a cutting tool lies; for it is impossible to make the cutting edge across the centre of the drill (that is, the cutting edge across the thickness of the drill, connecting the cutting edge of one side of the drill to the cutting edge of the other side, as shown at *A* in Fig. 1071) sufficiently keen to enable it to enter the metal easily, without grinding the angles of the two cutting edges very acute, as shown in the edge view of Fig. 1071 by the dotted lines, which would so weaken the cutting edges as to cause them to break from the pressure of even the lightest feeding. The only alternative, then, is to make the point of the drill as thin as is compatible with sufficient strength; and this will be found to be of about the following proportions:

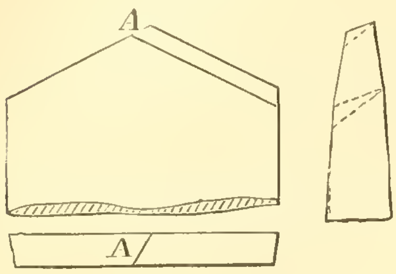
| Diameter of Drill. | Thickness at Point. | Diameter of Drill. | Thickness at Point. |
|---|---|---|---|
| 1-8 inch. | 1-64 inch. | 5-8 inch. | 1-16 inch. |
| 1-4 " | 1-32 " | 3-4 " | 1-16 " |
| 3-8 " | 3-64 " | 7-8 " | 1-16 " |
| 1-2 " | 1-16 " | 1 " | 3-32 " |

The flat face must be made gradually thicker as the full diameter of the drill is reached. The angle at which to grind the end of the drill is governed to a large extent by the kind and degree of hardness of the metal to be drilled, the angle shown in Fig. 1071 being suitable for wrought-iron, steel, or unusually hard cast-iron; while for common cast-iron or brass a little more angle may be given. But no definite angle can be given for any metal, because of the varying conditions under which a drill performs its duty. From these considerations we find that the effectiveness of a drill arises from the support rendered to it by the work, which more than compensates for the want of keenness inherent to its form of cutting edge.

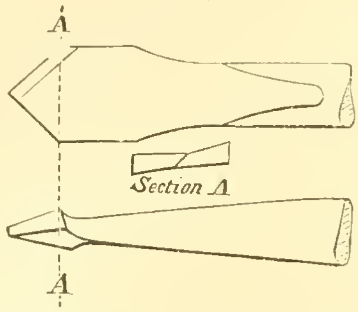
Thus far, however, we have been considering the ordinary flat drill in its most simple form. For use on steel, wrought-iron, and cast-iron, we may improve the cutting qualities of the drill by bending each side of the cutting bevel-edges forward, thus forming what is termed a lip drill, as shown in Fig. 1072. Such a drill will cut with much greater ease and rapidity, because the angle of the two faces whose junction forms a cutting edge is much more acute, while the cutting edge is at the same time well supported by the metal behind it, which advantages are to be obtained in no other way.

*The Twist-Drill*, with cutting edges like those last described, is formed by cutting two spiral flutes upon a cylindrical piece, as shown in Fig. 1073. Twist-drills are not of the same diameter from end to end of the twist, but are slightly taper, diminishing toward the shank end. The taper is usually,

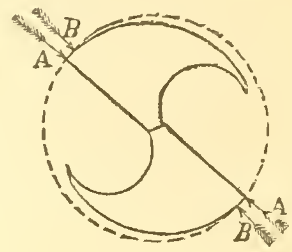
1071.




1072.




1073.

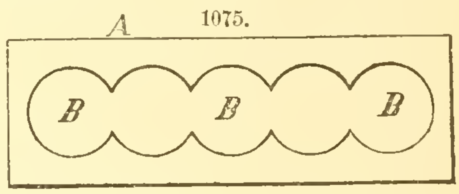



however, so slight as to be of little consequence in actual practice. Neither are twist-drills round, the diameter being eased away from a short distance behind the advance or cutting edge of the flute backward to the next flute, as in Fig. 1074. The object of this is to give the sides of the drill as much clearance as possible. The part of the circumference from *A* to *B*, on each side, is left of a full circle, which maintains the diameter of the drill and steadies it in the hole. If, from excessive duty, that part from *A* to *B* should wear away at the cutting end of the drill, leaving the corner of the drill rounded, the drill must be ground sufficiently to cut away entirely the worn part; otherwise it will totally impair the value of the drill, causing it to grind against the metal, and no amount of pressure will cause it to cut. To give these drills strength, the flutes are made shallower at and toward the shank.

The chief advantage over other drills possessed by twist-drills is, that the cuttings can find free egress, which effects a great saving of time; for plain drills have to be frequently withdrawn from the hole to extract the cuttings, which would jam between the sides of the hole and the sides of the drill, and the pressure will frequently become so great as to twist or break the shank of the drill, especially in small holes. In point of fact, the advent of twist-drills has rendered the employment of any other form for use in small holes (that is to say, from three-eighths of an inch downward) unadvi-

1074.

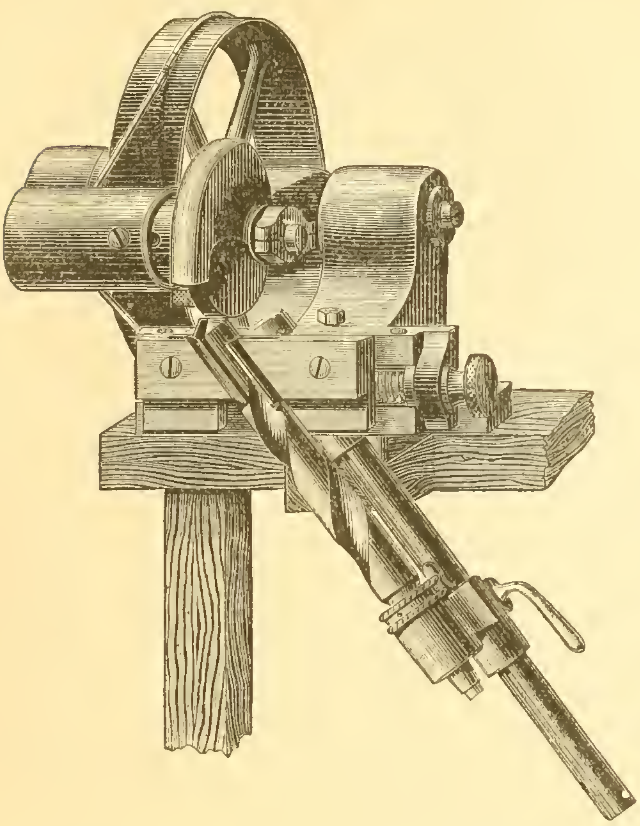
1075.



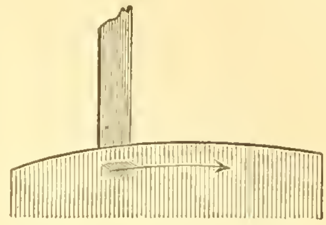

sable, except it be for metal so hard as to require a drill tempered to suit the work. The other advantages of the twist-drill are, that it always runs true, requires no reforging or tempering, and, by reason of its shape, fits closely to the hole, and hence drills a very straight and smooth hole. It is also not liable to be influenced so much by an air or other hole or soft spot which may exist in the metal being drilled. These qualities render the twist-drill a very superior tool for the finer classes of work, and for such purposes as drilling metal away to form a keyway or slot; for in the latter case the holes may be drilled so closely together that they will run one into the other, as shown in Fig. 1075, *A* being the piece of metal and *B B B* the holes. A common flat drill is incapable of performing such work. The twist-drill will not, however, in holes of a moderate depth (that is to say, holes whose depth is not more than four times their diameter), do so much duty in a given time as a common drill, especially if, in iron or steel, the latter be slightly lipped; the reason being that the latter, stronger in proportion to its diameter, will stand more strain, and may therefore be fed much more rapidly in all cases wherein the depth is not so great as to prevent the cuttings from finding egress before becoming jammed in the hole.

*Twist-Drill Grinding.*—Fig. 1076 represents Seller's drill-grinding machine, in which a twist-drill is shown in position to be operated upon. The end of the drill near to the cutting edges is held in a clamp-vise. The emery-wheel, passed back and forth over the lip, which is in a horizontal position, grinds it to a true line. Then, upon slacking the clamp-vise and turning the drill half-way around by means of an index-plate at the shank end of the drill, the other lip is in position to be ground to correspond with the first. This principle of clamping the end of the drill for each lip insures absolute equality in the length and cutting property of each, provided the last pass of the wheel over the two lips be made without vertical adjustment of the emery-wheel. The bar which carries the socket for holding the drill-shank is placed at an angle that has been found by experience to give the best average result in cast and wrought iron. The drill when clamped is so placed in regard to the emery-wheel as to insure proper clearance on fly-drills. Twist-drills will have clearance for their cut near the edge of the drill, but must be backed off up to this surface by hand on a grindstone. Fig. 1077 shows the position of the grinding wheel in reference to the edge of a fly-drill, and indicates the method of obtaining clearance. In setting a twist or fly drill in place in the clamping jaws, care must be taken to place its cutting edge as nearly as possible parallel with the line of motion of the wheel in passing back and forth over its length, as is shown in Fig. 1078 A for twist-drills, and Fig. 1078 B for fly-drills. Fly-drills made as shown in Fig. 1079 cannot be ground with any exactness; there should be a portion of the length of drill with parallel sides for some little distance above the lips, as is shown in Fig. 1080. This condition exists in twist-drills.

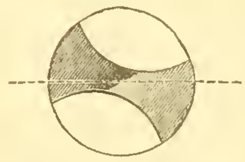
1076.



1077.

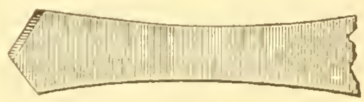


1078 A.



1078 B.

1079.

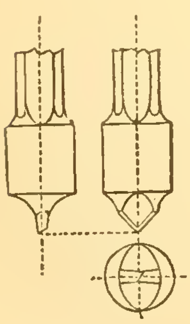


1080.

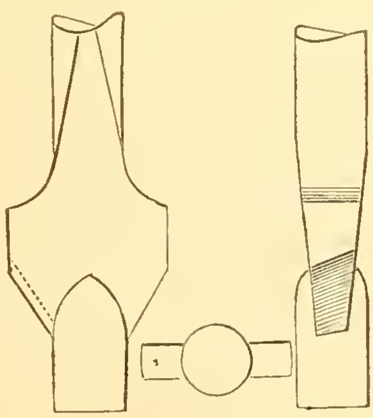
*The Recentering Drill* is represented in Fig. 1081. It is used for beginning a small hole in a flat-bottomed cylindrical cavity, or else in rotation with the common piercing drill and half-round bit in drilling small and very deep holes in the lathe.

*The Countersink.*—This tool is used for enlarging orifices. Fig. 1082 represents a taper countersink, such as is employed for rivet-holes requiring to be flush or even with the surface of the riveted plate. In tempering these tools, or any others having a pin or projection to serve as a guide in a hole, the tool should be hardened right out from the end of the pin to about three-eighths of an inch above the cutting edges. Then lower the temper of the metal (most at and near the cutting edges), leaving the pin of a light straw color, which may be accomplished by pouring a little oil upon it

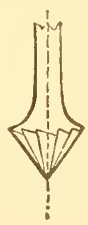
1081.



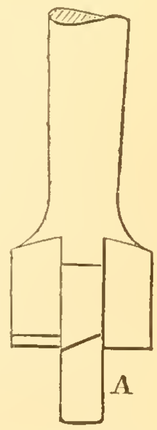
1082.



1083.



1084.

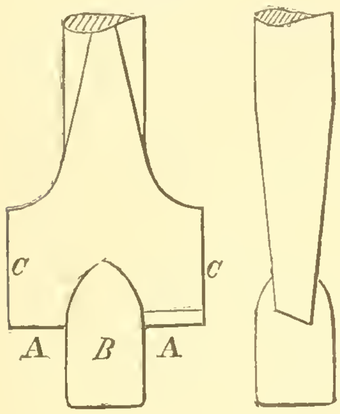



during the lowering or tempering process. The object of this is to preserve it as much as possible from the wear due to its friction against the sides of the hole. For use on wrought-iron and steel, this countersink (as also the pin-drill) may have the front face hollowed out.

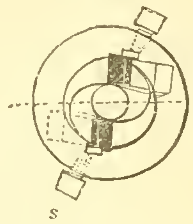
For use on holes half an inch and less in diameter, we may use a countersink made by turning up a cone, and filing upon it teeth similar to those upon a reamer, as shown in Fig. 1083; or we may take the same turned cone and cut it away to half its diameter, similar to a half-round bit. Either of these countersinks will cut true and smoothly, oil being applied when they are used upon steel or wrought-iron. Common drills, ground to the requisite angle or cone, are sometimes used as countersinks, but they are apt to cut central and uneven. For fine light work the pin-drill, with its cutting edges either at right angles to the centre line of the pin or at such other angle as may be required, forms the best countersink; it should, however, have more than two cutting edges, so that they may steady it. Fig. 1084 presents an excellent form of this tool, *A* being one of the four cutting edges. It is formed by turning up the whole body, filing out the necessary four spaces between the cutters, and backing the latter off at the ends only, so that the circumferential edges will not cut, and hence the recesses or countersinks will be all of one diameter.

*The Pin-Drill.*—This drill, Fig. 1085, has a pin projecting beyond and between its cutting edges, as shown, $A$ $A$ being the cutting edges. The use of this drill is to face off the metal round the outside of holes, the pin $B$ fitting into the hole so as to steady the drill, and keep it true with the hole. In making this tool, the pin $B$, the edges $C$, and the ends forming the cutting edges $A$ $A$, should be turned up true in the lathe; the backing off may then be filed, leaving the cutting edges $A$ $A$ with the turning marks barely effaced; thus they will be sure to be true and at an equal height from the end of the pin, so that both the cutting edges may operate. Roberts's pin-drill, represented in Figs. 1086 and 1087, has two grooves in its stock at an angle of about 10° with the axis, and rather deeper behind than in front. Two steel cutters or nearly parallel blades, represented in black, are laid in the grooves. They are fixed by the ring and two set-screws $s$ $s$, and are advanced, as they become worn away, by two adjusting screws $a$ $a$ (one of which only is shown) placed at an

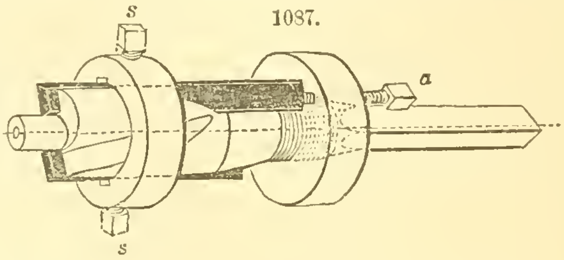
1085.




1086.




1087.

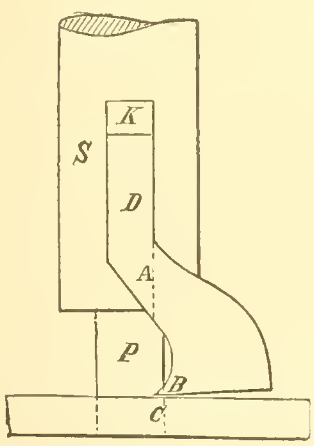



angle of 16° through the second ring, which for convenience of construction is attached to the drill-shaft just beyond the square tang whereby it is secured to the drilling machine. The object of this contrivance is to retain the dimensions and angles of the tool.

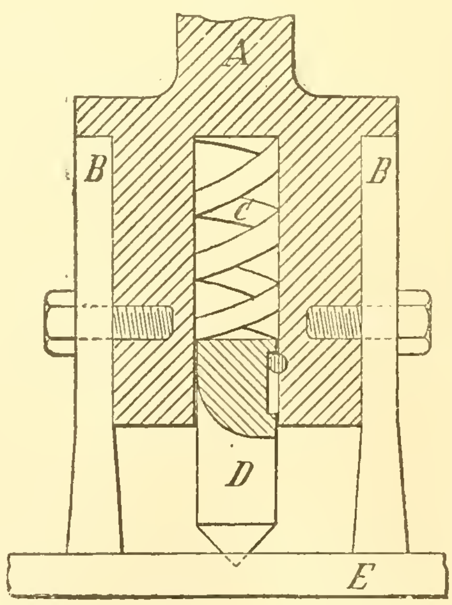
*Stock-Cutters.*—These cutters are held in a stock or bar, as shown in Fig. 1088, in which $S$ is the stock and $D$ the cutter, secured by the key $K$. It will be noted that the cutting edge $B$ stands in the rear of the line $A$, or fulcrum from which the springing takes place; hence, when the tool springs, it will recede from the work $C$. To avoid springing, and for very large holes, the cutter may be a short tool, held by a stout cross-bar carried by the stock; but in any event the cutter should be made as shown above. Cutters of a standard size, and intended to fit the pin-stock, should be recessed to fit the end of the slot in the stock. In making these cutters, they should be first fitted to the stock, and then turned up in the lathe, using the stock as a mandrel, the ends being then backed off to form the cutting edges.

The use of this class of cutter-stock involves the boring of a hole to receive the pin $P$. To avoid this, the tool shown in Fig. 1089 is employed. It consists of a stock $A$, to which are firmly bolted

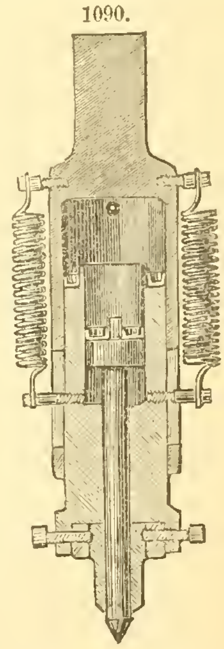
1088.




1089.




1090.



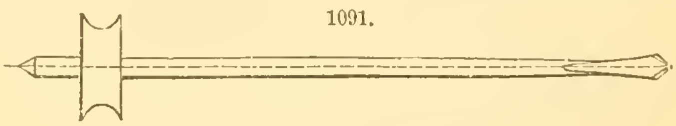
the cutters $B$ $B$. In $A$ is provided the hole containing the spiral spring $C$, operating upon the cylindrical centre, which is a sliding fit to the hole, and the point of which is forced into a centre-punch mark made in the plate by the spring $C$. Thus the centre $D$ serves as a guide to steady the cutters and cause them to revolve in a true circle, so that the necessity of first drilling a hole, as required in the employment of the form of stock shown in Fig. 1089, is obviated. The cutters are broadest at the cutting edge, which is necessary to give the point clearance in the groove. They are also made thinner behind at the taper part (that is to say, the part projecting below the stock) than at the cutting edge, which is done to give the sides clearance. It is obvious that, with suitable cutters, various-sized holes may be cut with one stock.

*Equilibrium Tool.*—Fig. 1090 is a section of McKay's equilibrium tool for drilling and boring tube-

plates. The outer case is a hydraulic cylinder which is fitted into the drilling-machine spindle socket; it contains an annular ram carrying cutters, inside of which is a steadying pin, with a piston at its upper end working in the cutter-ram. The cylinder is charged with soap and water, which forms the equilibrium medium, and when the tool is at rest the annular or cutter ram is kept up by two springs, one on each side, and the centre or steadying pin is full out. When at work, the action of the tool is as follows: The centre-pin is placed into a centre-pop, marked out as the work to be done requires; immediately the feed is put on, the tool is driven on to the centre-pin, which causes the fluid to force down the outer ram with cutters; a perfect equilibrium is maintained during the process of drilling by the fluid with which the tool is charged. When the hole is drilled, the springs draw up the cutter-ram and force out the centre-pin ready for another hole. Another form contains three separate rams: the centre ram is the steadying pin, and the two outer ones carry the cutters. The action of this machine when at work is in every respect similar to the above, except that the cutters are independent of each other, the three rams being all in equilibrium, and the cross-bars attached to springs on either side draw in the cutters, and throw out the steadying pin when the tool has completed the hole as above described. Among the advantages of this tool are stated to be saving of time and power. In drilling, after the centre-pivot is entered into the centre-pop, no further attention is required for centering, as the cutters at once cut a narrow groove into the surface of the plate, and have only the thickness of the plate to go through.

*Bow-Drills.*—The smallest holes are those required in watch-work, and the general form of the drill is shown on a large scale in Fig. 1091; it is made of a piece of steel wire, which is tapered off at one end, flattened with the hammer, and then filed up in form. The reverse end of the instrument is made into a conical point, and is also hardened; near this end is attached a little brass sheave for the line of the drill-bow, which in watchmaking is sometimes a fine horse-hair, stretched by a piece of whalebone of about the size of a goose's quill stripped of its feather.

1091.

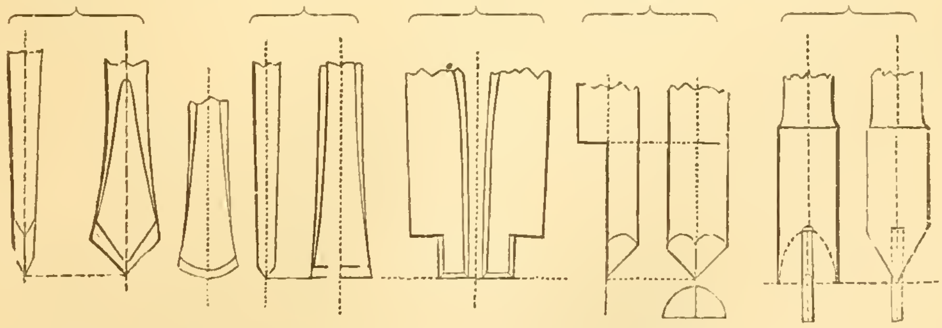


The watchmaker holds most of his works in the fingers, both for fear of crushing them with the table-vise, and also that he may the more sensibly feel his operations; drilling is likewise performed by him in the same manner. Having passed the bowstring around the pulley in a single loop (or with a round turn), the centre of the drill is inserted in one of the small centre-holes in the sides of the table-vise, and the point of the drill is placed in the mark or cavity made in the work by the centre-punch; the object is then pressed forward with the right hand, while the bow is moved with the left.

Clockmakers, and artisans in works of similar scale, fix the object in the tail-vise, and use drills such as Fig. 1091, but often larger and longer; they are pressed forward by the chest, which is defended from injury by the breastplate, namely, a piece of wood or metal about the size of the hand, in the middle of which is a plate of steel, with centre-holes for the drill. The breastplate is sometimes strapped round the waist, but is more usually supported with the left hand, the fingers of which are ready to catch the drill should it accidentally slip out of the centre. As the drill gets larger the bow is proportionally increased in stiffness, and eventually becomes the half of a solid cone, about an inch in diameter at the larger end and 30 inches long; the catgut string is sometimes nearly an eighth of an inch in diameter, or is replaced by a leather thong. The string is attached to the smaller end of the bow by a loop and notch, much the same as in the archery-bow, and is passed through a hole at the larger end, and made fast with a knot; the surplus length is wound round the cane, and the cord finally passes through a notch at the end, which prevents it from uncoiling. The comparative feebleness of the drill-bow limits the size of the drills employed with it to about one-quarter of an inch in diameter; but as some of the tools used with the bow agree in kind with those of much larger dimensions, it will be convenient to consider as one group the forms of the edges of those drills which cut when moved in either direction.

Figs. 1092, 1093, and 1094 represent, of their largest sizes, the usual forms of drills proper for the reciprocating motion of the drill-bow, because, their cutting edges being situated on the line of the axis, and chamfered on each side, they cut, or rather *scrape*, with equal facility in both directions of

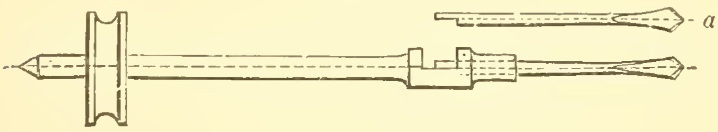
1092. 1093. 1094. 1095. 1096. 1097.



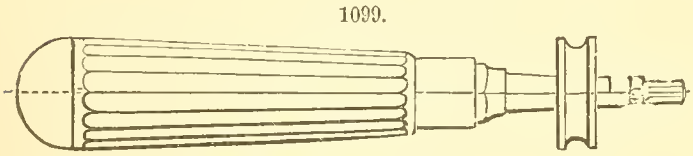
motion. Fig. 1092 is the ordinary double-cutting drill; the two facets forming each edge meet at an angle of about 50° to 70°, and the two edges forming the point meet at about 80° to 100°; but watchmakers, who constantly employ this kind of drill, sometimes make the end as obtuse as an angle of about 120°; the point does not then protrude through their thin works long before the completion of the hole. Fig. 1093, with two circular chamfers, bores cast-iron more rapidly than any other reciprocating drill, but it requires an entry to be first made with a pointed drill; by some, this kind is

also preferred for wrought-iron and steel. The flat-ended drill, Fig. 1094, is used for flattening the bottoms of holes. Fig. 1095 is a duplex expanding drill, used by cutlers for inlaying the little plates of metal in knife-handles; the ends are drawn full size. Fig. 1096 is also a double-cutting drill; the cylindrical wire is filed to the diametrical line, and the end is formed with two facets. This tool has the advantage of retaining the same diameter when it is sharpened; it is sometimes called the Swiss drill, and was employed by M. Le Rivière for making the numerous small holes in the delicate punching machinery for manufacturing perforated sheets of metal and pasteboard. These drills are sometimes made either semicircular or flat at the extremity; they are commonly employed in the lathe. The square countersink, Fig. 1097, is also used with the drill-bow; it is made cylindrical, and pierced for the reception of a small central pin, after which it is sharpened to a chisel-edge, as shown. This countersink is in some measure a diminutive of the pin-drills, and occasionally circular collars are fitted on the pin for its temporary enlargement, or around the larger part to serve as a stop, and limit the depth to which the countersink is allowed to penetrate, for inlaying the heads of screws. The pin is removed when the instrument is sharpened. Steel bows are also occasionally used; these are made something like a fencing foil, but with a hook at the end for the knot or loop of the cord, and with a ferrule or a ratchet, around which the spare cord is wound. Some variations also are made in the sheaves of the large drills. Sometimes they are cylindrical with a fillet at each end; this is desirable, as the cord necessarily lies on the sheave at an angle, in fact in the path of a screw; it pursues that path, and with the reciprocation of the drill-bow the cord traverses, or screws backward and forward upon the sheave, but is prevented from sliding off by the fillet. Occasionally, indeed, the cylindrical sheave is cut with a screw coarse enough to receive the cord, which may then make three or four coils for increased purchase, and have its natural screw-like run without any fretting whatever; but this

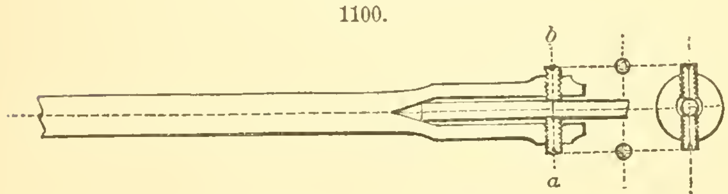
1098.




1099.



1100.

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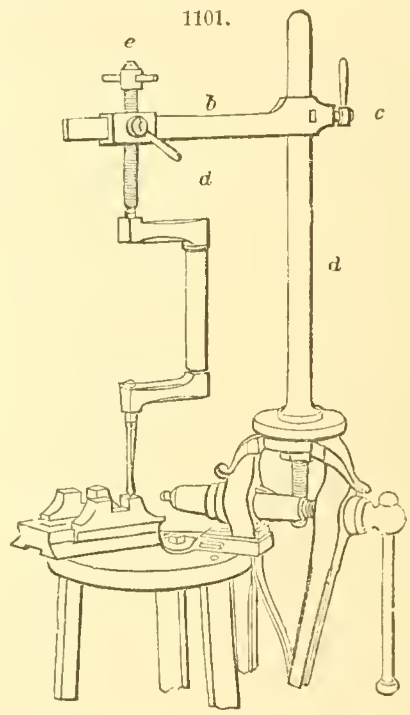



is only desirable when the holes are large and the drill is almost constantly used, as it is tedious to wind on the cord for each individual hole. The structure of the bows, breastplates, and pulleys, although often varied, is sufficiently familiar to be understood without figures. When the shaft of the drill is moderately long, the workman can readily observe if the drill is square with the work as regards the horizontal plane; and to remove the necessity for the observation of an assistant as to the vertical plane, a trifling weight is sometimes suspended from the drill-shaft by a metal ring or hook; the joggling motion shifts the weight to the lower extremity: the tool is only horizontal when the weight remains central.

*Drill-Stocks.*—The necessity for repeating the shaft and pulley of the drill is avoided by the employment of holders of various kinds, or *drill-stocks*, which serve to carry any required number of drill-points. The most simple of the drill-stocks is shown in Fig. 1098; it has the centre and pulley of the ordinary drill, but the opposite end is pierced with a nearly cylindrical hole, just at the inner extremity of which a diametrical notch is filed. The drill is shown separately at *a*; its shank is made cylindrical, or exactly to fit the hole, and a short portion is nicked down also to the diametrical line, so as to slide into the gap in the drill-stock, by which the drill is prevented from revolving; the end serves also as an abutment whereby it may be thrust out with a lever. Sometimes a diametrical transverse mortise, narrower than the hole, is made through the drill-stock, and the drill is nicked in on both sides. The cylindrical hole of Fig. 1098 should be continued to the bottom of the notch, the end of the drill should be filed off obliquely, and it should be prevented from rotating by a pin inserted through the cylindrical hole parallel with the notch; the taper end of the drill would then wedge fast beneath the pin.

Drills are also frequently used in the *drilling-lathe*; this is a miniature lathe-head, the frame of which is fixed in the table-vise; the mandrel is pierced for the drills, and has a pulley for the bow, therein resembling Fig. 1099, except that it is used as a fixture.

Fig. 1099 represents one variety of another common form of drill-stock, in which the revolving spindle is fitted in a handle, so that it may be held in any position, without the necessity for the breast-plate; the handle is hollowed out to serve for containing the drills, and is fluted to assist the grasp.

Fig. 1100 represents the socket of a "*universal drill-stock*," invented by Sir John Robinson; it is pierced with a hole as large as the largest of the wires of which the drills are formed, and the hole terminates in an acute hollow cone. The end of the drill-stock is tapped with two holes, placed on a diameter; the one screw, *a*, is of a very fine thread, and has at the end two shallow diametrical notches; the other, *b*, is of a coarser thread and quite flat at the extremity. The wire drill is placed against the bottom of the hole, and allowed to lean against the adjusting screw *a;* and if the drill be not central, this screw is moved one or several quarter turns, until it is adjusted for centrality, after which the tool is strongly fixed by the plain set-screw *b.*

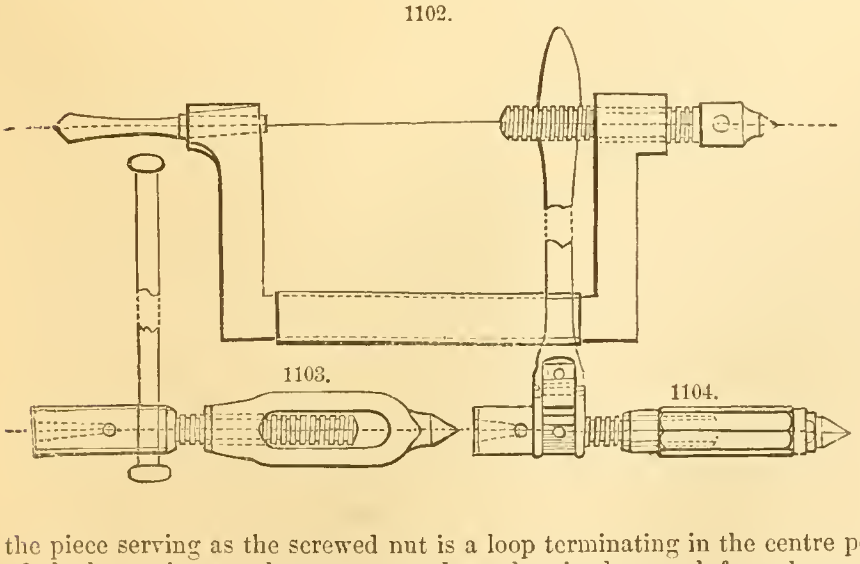
Fig. 1101 will serve to show the general character of various forms of apparatus to be used for supplying the pressure in drilling holes with hand-braces. It consists of a cylindrical bar *a*, upon which the horizontal rectangular rod *b* is fitted with a socket, so that it may be fixed at any height, or in any angular position, by the set-screw *c.* Upon *b* slides a socket, which is fixed at all distances from *a* by its set-screw *d;* and lastly, this socket has a long vertical screw *e*, by which the brace is thrust into the work. The object to be drilled having been placed level, either upon the ground, on trestles, on the work-bench, or in the vise, according to circumstances, the screws *c* and *d* are loosened, and the brace is put in position for work. The perpendicularity of the brace is then examined with a plumb-line, applied in two positions (the eye being first directed as it were along the north and south line, and then along the east and west), after which the whole is made fast by the screws *c* and *d.* One hole having been drilled, the socket and screws present great facility in readjusting the instrument for subsequent holes, without the necessity for shifting the work, which would generally be attended with more trouble than altering the drill-frame by its screws. Sometimes the rod *a* is rectangular, and extends from the floor to the ceiling; it then traverses in fixed sockets, the lower of which has a set-screw for retaining any required position. In the tool represented, the rod *a* terminates in a cast-iron base, by which it may be grasped in the tail-vise, or when required it may be fixed upon the bench. In this case the nut on *a* is unscrewed; the cast-iron plate, when reversed and placed on the bench, serves as a pedestal; the stem is passed through a hole in the bench, and the nut and washer, when screwed on the stem beneath, secure all very strongly together. Even in establishments where the most complete drilling machines driven by power are at hand, modifications of the press-drill are among the indispensable tools; many are contrived with screws and clamps, by which they are attached directly to such works as are sufficiently large and massive to serve as a foundation.

Various useful drilling tools for engineering works are fitted with left-hand screws, the unwinding of which elongates the tools; so that for these instruments, which supply their own pressure, it is only necessary to find a solid support for the centre. They apply very readily in drilling holes within boxes and panels, and the abutment is often similarly provided by projecting parts of the castings; or otherwise the fixed support is derived from the wall or ceiling, by aid of props arranged in the most convenient manner that presents itself.

Fig. 1102 is the common brace, which only differs from that in Fig. 1101 in the left-hand screw; a right-hand screw would be unwound in the act of drilling a hole when the brace is moved round in the usual direction, which agrees with the path of a left-hand screw. The cutting motion produces no change in the length of the instrument, and the screw, being held at rest for a moment during the revolution, sets in the cut; but toward the last the feed is discontinued, as the elasticity of the brace and work suffices for the reduced pressure required when the drill is nearly through, and sometimes the screw is unwound still more to reduce it.

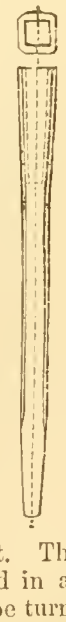
The *lever-drill*, Fig. 1103, differs from the brace-drill in many respects; it is much stronger, and applicable to larger holes; the drill-socket is sufficiently long to be cut into the left-hand screw, and

1102.



1103. 1104.

1105.

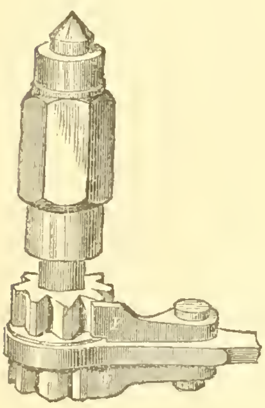


1106.

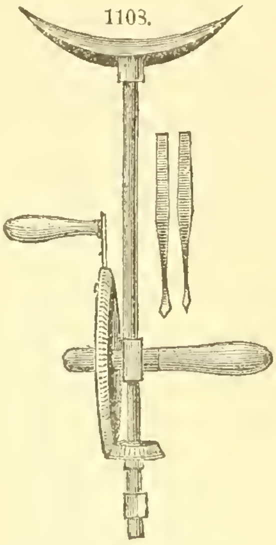

the piece serving as the screwed nut is a loop terminating in the centre point. The increased length of the lever gives much greater purchase than in the crank-form brace, and in addition the lever-brace may be applied close against a surface where the crank-brace cannot be turned round; in this case the lever is only moved a half circle at a time, and is then slid through for a new purchase, or

sometimes a spanner or wrench is applied directly upon the square drill-socket. The same end is more conveniently fulfilled by the *ratchet-drill*, Fig. 1104, apparently derived from the last; it is made by cutting ratchet-teeth in the drill-shaft, or putting on the ratchet as a separate piece, and fixing a pawl or detent to the handle; the latter may then be moved backward to gather up the teeth, and forward to thrust round the tool, with less delay than the lever in Fig. 1103, and with the same power, the two being of equal length. This tool is also peculiarly applicable to reaching into angles and places in which neither the crank-form brace nor the lever-drill will apply. Fig. 1105 is used for lengthening drills, and is simply a bar having at one end a socket for the drill and at the

1107.



1108.



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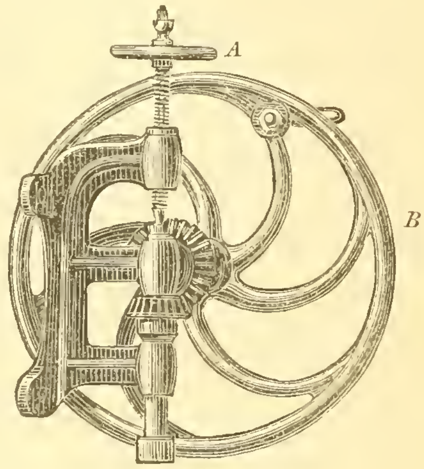
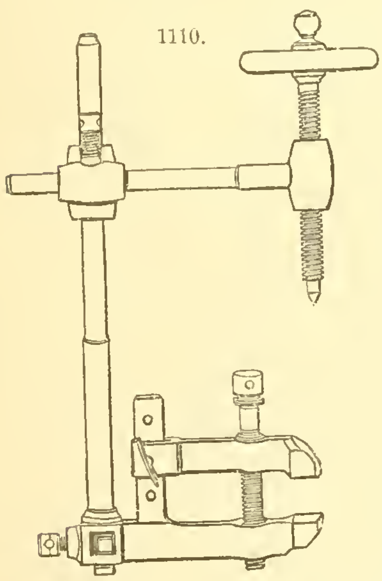


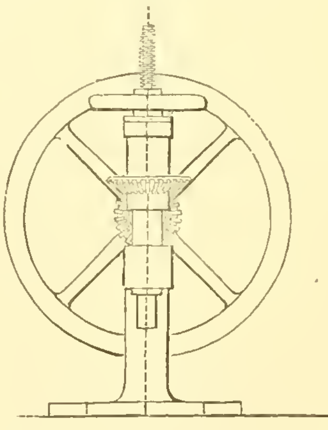

other a tang to fit the brace. Fig. 1106, the *ratchet-lever*, in part resembles the ratchet-drill; but the pressure-screw of the latter instrument must be sought in some of the other contrivances referred to, as the ratchet-lever has simply a square aperture to fit on the tang of the drill *d*, which latter must be pressed forward by other means. Fig. 1107 exhibits the construction of the ratchet-drill more in detail, *F F* being the ratchet.

In Fig. 1108 is shown a simple form of breast-drill, the construction of which is obvious from the engraving. Fig. 1109 represents a hand-drilling machine designed for attachment to a wall or post. *A* is the feed-wheel, and *B* the crank whereby the drill is rotated. A useful combination of drill and vise is shown in Fig. 1110. In Figs. 1111 and 1112 is represented a simple drill in which the spindle is driven by a pair of bevel-pinions; the one is attached to the axis of the vertical fly-wheel, the

1110.



1111.



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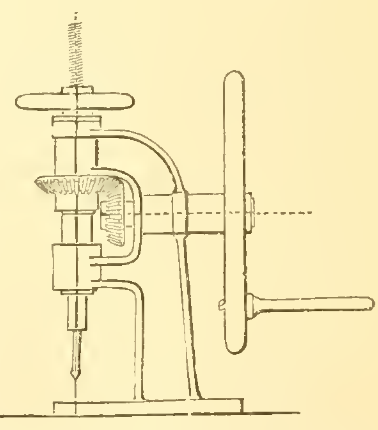
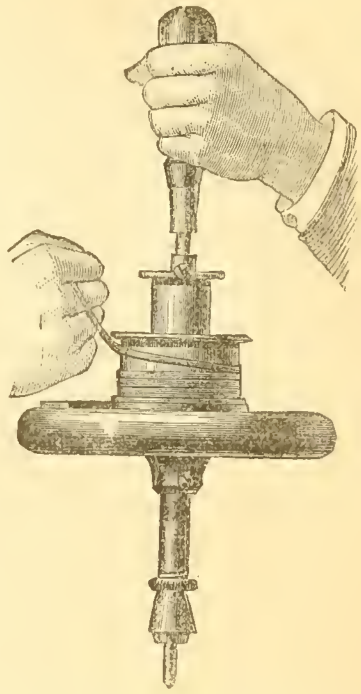


other to the drill-shaft, which is depressed by a screw moved by a small hand-wheel. Sometimes, as in the lathe, the drilling-spindle revolves without endlong motion, and the table is raised by a treadle or by a hand-lever; but more generally the drill-shaft is cylindrical and revolves in, and also slides through, fixed cylindrical bearings. The drill-spindle is then depressed in a variety of ways; sometimes by a simple lever, at other times by a treadle which either lowers the shaft only one single sweep, or by a ratchet that brings it down by several small successive steps through a greater distance; and mostly a counterpoise weight restores the parts to their first position when the hand or foot is removed. Friction-clutches, trains of differential wheels, and other modes, are also used in depressing the drill-spindle, or in elevating the table by self-acting motion. Frequently also the platform admits of an adjustment independent of that of the spindle, for the sake of admitting larger pieces; the horizontal position of the platform is then retained by a slide, to which a rack and pinion movement, or an elevating screw, is added.

Fig. 1113 represents a quick-speed hand-drill designed for light drilling in wood or metal. Its chief parts are a fly-wheel carrying the drill, and a pulley spring and clutch mechanism, all of which revolve loosely on a spindle held stationary by a handle. The action is as follows: By drawing with one hand a string wound around the drum, the latter and the clutch, together with the fly-wheel

and drill, are set in motion at a certain speed. At the same time the spring attached to the drum is tightened. As soon as the tension of the hand holding the string is relaxed, the movement of the pulley is reversed, taking up the slack at the same time. The fly-wheel and the drill do not, however, take part in the reversal of the motion, owing to the action of the clutch. A continuous revolving movement in one direction is thus insured for the drill, the speed varying from 500 to 1,000 revolutions per minute.

1113.



*Drilling Square Holes.*—Mr. Julius Hall of London has devised an ingenious method of drilling a square hole by a rotary drill. For this purpose a three-sided drill is used, either flat or fluted, having its bottom or cutting edges perfectly flat, and three in number, each cutting edge extending from one of the outer corners to the centre of the triangle. The drill is held in a specially constructed chuck, so made as to allow the tool to have some horizontal travel, or, in plain terms, to allow it to "wobble." The horizontal travel or play is proportionate to the size of the hole to be drilled. Near to the lower end or cutting edges of the drill is fixed rigidly a metal guide-bar or plate. The guide-bar is provided with a square hole similar to the hole it is required to drill, the dimensions of the three sides of the drill being such that the distance from the base to the apex of the triangle which such three sides form is the same as of the sides of the square holes it is required to drill. The method of operation is as follows: The three-sided drill being fixed in the self-adjusting chuck, the guide-bar with the square guide-hole therein rigidly fixed above the point where it is required to drill, the drilling-spindle carrying the chuck-drill is made to revolve, and is screwed or pressed downward, upon which the drill works downward through the square guide-hole, and drills holes similar in size and form to that in the guide. The triangular drill may also be used in any ordinary chuck, when the substance operated upon is not very heavy nor stationary; then, instead of the lateral movement of the drill obtained as described, such lateral movement will be communicated to the drill by the substance operated upon. (See "Wrinkles and Recipes," New York, 1878, and *Scientific American*, xxxix., 311.) J. R. (in part).

DRIVE-WELL. See Well-boring.

DRYER. See Sugar Machinery.

DRYING MACHINE. See Paper-making.

DYNAMICS, properly speaking, is the science which treats of forces in the abstract; but in an extended sense it is defined as the science which treats of the movement of bodies, and of the laws of the forces which produce the movement. The latter, however, is properly the definition of kinetics, but we shall use the former in its extended sense. This science was founded by Galileo, and had its birth in the establishment of the principle of accelerating forces. Sir Isaac Newton stated its fundamental principles in the form of three laws:

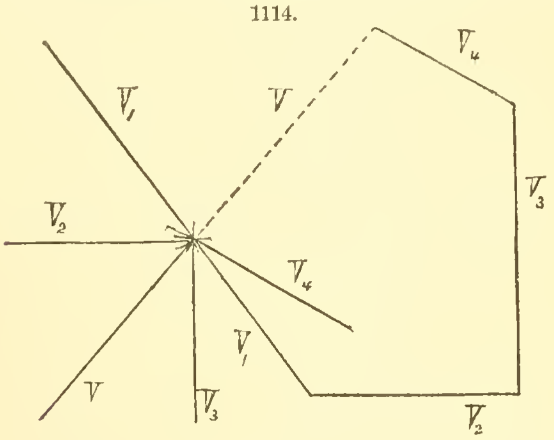
Fundamental Laws.—1. *Every body continues in a state of rest or of uniform motion in a straight line, unless acted on by a force which compels a change.* This law expresses the fact that matter is inert and perfectly passive; that it cannot of itself change its position of rest or condition of motion; and that every change is due to an adequate cause. It has been determined that the molecules of a body may be in a state of rapid motion in reference to each other, while the body as a whole is considered at rest. It is necessary, therefore, to consider the term body as applicable to a mere particle, unless otherwise stated. By a particle we mean the smallest conceivable portion of a body.

2. *Change of motion is proportional to the acting force, and takes place in the direction in which the force acts.* The term *motion* here includes all the elements of the body which enter into the motion, and hence involves both the mass and velocity; but these jointly are called the momentum of the body; hence the law should read: The change of momentum of a body is proportional to the acting force. This change, then, is recognized as a measure of the cause which produces the change. It is the first principle upon which analysis is founded. If a body at rest be acted upon by a single force, it is evident that its line of motion must coincide with the line of action of the force; but if a body be in motion, a force which acts at an angle with the line of motion will deflect the body from that line, but the resultant motion will not generally coincide with the line of action of the force. The effect, however, will be in the *direction* of action, that is, in a line parallel to the action of the force. Thus, if a body be moving southerly in the plane of a meridian, and a force acts upon it in a due easterly direction, the resulting motion of the body will not be due east, but its deviation from the plane of the meridian will be just as much to the east of that plane as if the body had been at rest when the force acted. Lagrange states this principle thus: "If different movements be impressed upon a body at the same time, the body at each instant will be found in the same place where it would be if all the movements were combined." Newton by means of this law established the parallelogram of forces. To illustrate: If a body describe the side of a polygon (Fig. 1114) with a uniform velocity of $V_1$ in one second, and then be brought to rest; and the side $V_2$ in the same time, and then be brought to rest; and $V_3$ and finally $V_4$ in the same manner; if now it were possible for these movements to take place at the same time, the body would be found at $V_4$ at the end of one second; and if all these movements be impressed upon the body at the same time, it will move over the side $V$ in one second. The acting force is the resultant of all the forces acting upon a body at any instant. This law fully stated would read: An acting force is one which produces a change in the velocity of a body, and is proportional to the rate of change of

the momentum produced in the body; its effect will be parallel to its line of action, and be independent of the state of the body in regard to rest or motion at the time of action of the force.

3. *Action and reaction are equal, but in contrary directions.* Newton gave three illustrations of this law, as follows: 1. If one presses a stone with his finger, his finger is also pressed by the stone. 2. If a horse draws a load, the horse is drawn backward, so to speak, equally toward the load. 3. If one body impinges upon another and changes the motion (momentum) of the other body, its own motion experiences an equal change in the opposite direction. These illustrations, if unaccompanied by explanations, are liable to mislead. Thus, if the load draws the horse back as much as the horse draws the load, there will be equilibrium, and no motion will result from the effort. So in regard to the first illustration, the question arises, how can a stone or other inert body exert any force? An erroneous view of the law will result if we consider the action as produced by a single body, or, generally, as an action within the bodies. The action is really *between* bodies. At least two bodies are always involved in an action, and a force never acts upon a single body only. When a ball is fired from a gun, the force of the powder acts equally against the ball and the gun. Attraction always exists between two or more bodies at the same time, and never acts upon one body only. If the action of the force be in one direction in reference to one body, it will be in exactly the contrary direction in reference to the other body; and if in one direction it is called an *action*, then in the opposite direction it is called a *reaction*. Action and reaction are precisely the same things in a mechanical sense; they are simply two names for designating the contrary actions of the same force. It is the force which acts equally in contrary directions, and not the bodies. Thus, when the horse draws a load, an action is induced between the breast of the horse and the collar against which he presses, and to maintain the pressure the horse pushes against the earth. The horse and load move

1114.

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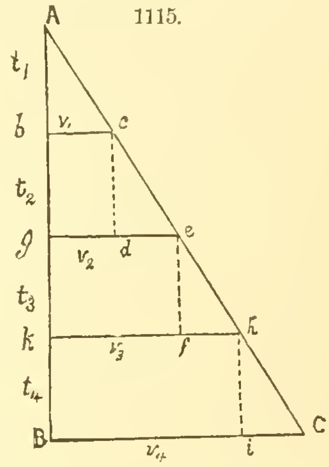


in one direction, and the earth moves a corresponding amount in the opposite direction; the action and reaction of the force between the horse and his harness are equal and opposite; also the force between the foot of the horse and the earth are equal and opposite. When the action is of sufficient intensity to move the load in one direction, something, though it be the earth, must move in the other direction. The law therefore ought to read: Every force acts upon two or more bodies at the same time, and its intensity is equal in contrary directions. This corresponds to the great modern doctrine of energy, which will be found discussed further on.

*Illustrations.*—1. If two boats of equal size, resting upon still water, are connected by a rope, and a man in one boat pulls on the rope with a force of 100 lbs., the boats will approach each other with equal velocities. And if a man in the other boat pulls on the same rope with a force of 100 lbs., they will not approach each other any faster. They will meet at a point midway between the boats. 2. If several spring-balances are attached end to end, and a man pulls at one end with a force of 50 lbs., each of the balances will indicate 50 lbs. if they are all accurate. 3. If two men pull at the ends of a rope in opposite directions, each with a force of 50 lbs., the tension of the rope is 50 lbs. and not 100 lbs.; for the action of one is the reaction of the other. 4. If a ball fired from a gun were as heavy as the gun, the gun would fly in one direction as fast as the ball went in the opposite direction; and if the ball were heavier than the gun, the gun would be shot away from the ball, so to speak, instead of the ball away from the gun.

The subject of motion may be considered independently of any cause producing it. When thus treated, it is called *kinematics*, or the science of pure motion.

VELOCITY is rate of motion. The term *rate* implies a comparison with some unit chosen as a standard. In regard to motion, the unit of reference is time, and may be a second, minute, hour, day, year, or century. In financial matters, the unit may be a dollar, or the English pound sterling, as when we speak of rate of interest, rate of exchange; and in other commercial matters we have rates of transportation, etc. Velocity is uniform when the body passes over equal successive portions of space in equal times, and in all other cases it is variable. In the definition for uniform velocity, it must be understood that the equal portions of space may be chosen arbitrarily. In periodic motion, in which the motion is repeated, like that of the vibrations of a pendulum, the times of successive vibrations may be equal, but the velocity along the path may constantly vary. If the velocity be uniform, it is measured by the space over which the body moves in a unit of time; so that if the body moves over the space ($s$) in a given time ($t$), we have for its velocity ($v$), $v = \frac{s}{t}$; or *uniform velocity is found by dividing the space passed over by the time.* If the velocity be

variable, it is measured by the space over which the body would pass in a unit of time if it moved with the velocity which it had at the instant considered. Most of the investigations in regard to variable velocity are best made by means of the calculus, but it may be determined to any degree of approximation by finding the space passed over in a very small portion of time. We have generally *variable velocity equal to infinitesimal space divided by corresponding infinitesimal time.* When the velocity varies at a uniform rate, it may easily be determined if the velocity at any two instants be known. Thus, suppose that a body starts from rest, and moves with a uniformly increasing velocity, acquiring a velocity $v_1$ at the end of the first second (Fig. 1115); then will the velocity at the end of two seconds be $2\ v_1$, at the end of three seconds be $3\ v_1$, and so on; and hence, at the end of $t$ seconds the velocity would be $t\ v_1$. In other words, *the velocity at the end of a given number of seconds will equal the velocity at the end of the first second multiplied by the number of seconds.*

*Angular velocity* is rate of angular movement. If the path of a body be a circle and the velocity uniform, the angular velocity will be the quotient arising from dividing the actual velocity by the radius of the circular path. The result may be reduced to degrees if desirable, but in this case it will generally be better to find it directly in that form.

*Examples.*—1. Required the angular velocity of the earth in its rotation on its axis. The earth turns on its axis once in 24 hours, that is, in that time it turns through $360°$; in one hour its angular velocity is $360° \div 24 = 15°$; and for one minute it is $15° \div 60 = 15'$; and for one second it is $15' \div 60 = 15''$.

2. The angular velocity of a fly-wheel whose radius is 5 feet is 1000° per second: what will be the actual velocity of a point on the circumference? The wheel will turn around $\frac{1000}{360} = 2\frac{7}{9}$ times in a second. The circumference will be $10 \times 3.1416 = 31.416$ feet; hence the velocity will be $2\frac{7}{9} \times 31.416 = 87.26$ feet per second.

If the motion be not along a circular path, and the velocity is variable, we must find the angular velocity for an instant. This is best done by the use of the calculus, and for the demonstration the reader is referred to the treatises noted at the end of this article.

Acceleration is the rate of change of velocity. If the acceleration be increasing, it is considered positive; if decreasing, negative. If the velocity increase at a uniform rate, the acceleration will be measured by the increase of the velocity for a unit of time. The unit is understood to be one second unless otherwise stated. If the acceleration be variable, it will be measured by the amount by which the velocity would be increased (or decreased) in a unit of time if the rate of increase had continued the same as at the instant considered. This principle is fundamental in this science; so much so, that dynamics has been defined as the science of accelerations. To find the velocity ($v$) of a uniformly accelerated body at the end of a given time ($t$), we have only to multiply the time by the acceleration ($f$) for one second, or $v = f\,t$. *Example:* Required the velocity of a body starting from rest, which is uniformly accelerated at the rate of 2 feet per second, at the end of 5 seconds. $v = 2 \times 5 = 10$ feet per second. To find the space ($s$) passed over in a given time ($t$), multiply the time by one-half the velocity corresponding, or $s = \frac{1}{2}\,v\,t$. *Example:* Required the space passed over by a body, which is uniformly accelerated at the rate of 2 feet per second, in 5 seconds. From the preceding example the velocity at the end of 5 seconds is 10 feet; then $s = \frac{1}{2} \times 10 \times 5 = 25$ feet.

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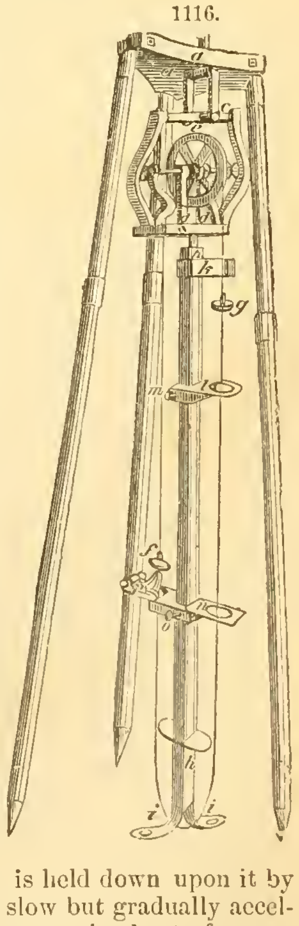

Falling Bodies.—Recognizing, as we now do, that bodies fall to the earth on account of the action of the force of gravity, and that within small distances from the surface of the earth the force is constant, we may deduce the laws of falling bodies directly. Galileo rather assumed than demonstrated that Nature would seek the simplest mode of action, and that the simplest law was that in which the variation of the velocity is uniform. The assumption was correct, and by means of it the laws were deduced. The principle of "Attwood's machine" for this purpose consists in counteracting a portion of the gravitating power of a body by the gravitating power of a smaller body; so that the absolute velocity and the spaces passed through shall be less than in the case of bodies descending freely, while, as the force is constant, the same ratio of progression will hold in both cases. Fig. 1116 represents the machine. $a\ a\ a$ is a triangular frame upon three movable legs; $b$, a small platform suspended from it by a universal joint $c\ c$, and supporting two upright standards $d\ d$, in which the axis of a light brass wheel $e$ revolves with very little friction. Over a groove in the periphery of the wheel passes a very light and pliable silk thread, from the ends of which hang two equal weights $f\ g$. Into the under side of $b$ is screwed a square rod $h$, descending to the floor, to which it is secured in a perpendicular position by small pins passing through holes in the claws $i\ i$: on the face of the rod is a scale of inches; $k$ is a brass guide, fixed at the upper part of the rod $h$, so that when the top of the weight $g$ touches the lower side of $k$, the under side of $g$ is on a level with the top, or commencement of the scale; $l$ is a small stage, movable along the rod $h$, and having a hole in it sufficiently large for the weight $g$ to pass: on one side is a tightening-screw $m$; $n$ is another movable stage, fitted with a tightening-screw $o$, as also a fork $p$, turning upon a hinge. The experiment is conducted as follows: A small circular weight is placed upon $g$, which is pulled up to the top of the scale, and the stage $n$ is screwed to the rod $h$, on a level with the lower part of the weight $f$, which is held down upon it by the fork $p$. Upon releasing $f$ from the fork, the weight $g$ descends with a slow but gradually accelerated motion, and the number of inches the weight has descended at each successive beat of a pendulum (suspended from another triangle) is observed upon the scale; and if the additional weight be

such as to cause $g$ to descend through 3 inches in the first second, then it will cause it to descend through 1 foot in 2 seconds, and through $6\frac{1}{4}$ feet in 5 seconds. It will be observed that the spaces vary as the squares of the times; thus, in 2 seconds the space is $3 \times 2^2 = 12$ inches = 1 foot; in 5 seconds the space is $3 \times 5^2 = 75$ inches = $6\frac{1}{4}$ feet. If the additional weight be removed, and a small bar of equal weight, but of a length exceeding the diameter of the hole in $l$, be placed upon $g$, and the stage $l$ be set at any division of the scale at which the weight would arrive at the end of any number of seconds, the stage will intercept the bar in its descent, and the weight will continue to descend with the velocity it had acquired upon reaching $l$. Thus, if the velocity at the end of the second second be 2 feet, in which case the weight would have descended 1 foot in that time, if the stage be set at 1 foot upon the scale, it will intercept the bar at the end of the second second, and the weight $g$ will move with a uniform velocity of 2 feet per second through the remaining portion of its descent. If it is required to illustrate the case of retarded motion, the small circular weight is placed upon the weight $g$, and a smaller weight upon the weight $f$, so that $g$ will still descend; but as soon as the stage $l$ intercepts the bar with the small weight upon it, $f$ becomes the heaviest, and $g$ will descend with a velocity decreasing as the squares of the times, counted from the time of $g$ passing the stage $l$.

By direct experiment it may be shown that the velocity of a falling body *in vacuo* at the end of one second is about $32\frac{1}{6}$ feet per second, usually represented by the symbol $g$; and this is the acceleration required. It is not, however, the same at all places on the earth: it will be greater at or near the poles, and less at the equator; it will be less on a high mountain than at its foot; it will be less at the bottom of a deep mine, if that point be below the natural surface of the earth; still, in all practical cases, it is so near $32\frac{1}{6}$ feet that this value may be used, except where great accuracy is demanded. This value of $g$ corresponds with the $f$ in the preceding paragraph, and substituting $32\frac{1}{6}$ for it, we have $v = 32\frac{1}{6}\,t$, $s = 16\frac{1}{12}\,t^2$; and from these we find $v = 8\sqrt{s}$ nearly; $v = \frac{2\,s}{t}$; $s = \frac{v^2}{64\frac{1}{3}}$; $s = \frac{1}{2}\,v\,t$; which are the formulas for falling bodies.

*Examples.*—1. How far will a body fall in five seconds? Here we have $s = 16\frac{1}{12}\,(5)^2 = 402.08$ feet. 2. What velocity will a body acquire in falling 100 feet? Here we have $v = \sqrt{64\frac{1}{3} \times 100} =$ 80 feet nearly. 3. What velocity will a body acquire that is falling four seconds? Here we have $v = 32\frac{1}{6} \times 4 = 128\frac{2}{3}$ feet.

The law of ascent is exactly the reverse of that of descent. In the ascent the velocity will decrease uniformly. If a body be projected upward with a given velocity, it will rise to the same height that it would be necessary for the body to fall in order to acquire that velocity.

When the resistance of the air is considered, these formulas are all modified. The resistance of the air varies nearly as the square of the velocity; so that when the velocity is great the resistance is also great, and the velocity as a consequence will be greatly reduced. If a body be projected upward in the air with a given velocity, it will return with a less velocity. The resistance acts against the velocity in both the upward and downward movements, tending constantly to diminish it. The acceleration of bodies falling in the air is not therefore uniform in any case, but may be considered as such when the fall is not more than 200 or 300 feet. When the resistance of the air is considered, the solution of the problem of the ascent and descent of bodies requires analysis of a high order.

Force moves or tends to move any body upon which it acts. Of its essential nature we know nothing, for it is unknowable. Laplace says: "The nature of that singular modification by means of which a body is transported from one place to another is now, and always will be, unknown; it is denoted by the name of Force." (Mécanique Céleste," p. 1.) All that we pretend to know in regard to it is its laws of action, and these must be learned by observation. Force may properly be regarded as *an action between bodies*. There are numerous cases, however, in which the action upon one body only is considered. Thus, when a projectile is fired from a gun, it is not generally necessary to consider the motion of the gun, but that of the ball only. In considering the attraction of the sun upon the planets, it is not necessary to consider the effect of the attraction of the planets upon the sun; for that body is so large compared with any one or even with all of the planets, that their combined effect is scarcely appreciable. A force, strictly speaking, is always balanced, for its intensity is equal in contrary directions. Still we often see the expression "unbalanced force." This is correct only when used in reference to its action upon a single body. The term force has many different names, such as attractive force, repulsive force, central force, centrifugal force, chemical force, force of electricity, etc.; but these only define the mode or character of its action. The intensity of a force is measured by pounds or their equivalent in English units, by kilogrammes or their equivalent in French units, etc. Any effect produced by a force, or any expression into which force enters, which cannot be measured by pounds or their equivalent, is not properly *force*. In this sense such expressions as force of momentum, force of *vis viva*, force of work, etc., are improper. The measure of force here given is generally called its statical measure, but its value is the same whether it produces motion or results only in pressure. Force may also be measured by the change of motion which it is capable of producing in a unit of time.

*Action at a distance* implies that a force may produce an effect upon a body at a distance without any medium between the force and body. Our first experience is opposed to this. The boy draws his sled or wagon by means of a rope extending from his hand to the sled; a man's voice is heard at a distance by means of the air; electricity produces an effect hundreds of miles distant through the medium of a wire; and we are led to suppose that a force cannot act except through a medium. But a magnet will attract iron when placed in the most perfect vacuum, and hence when there is no apparent medium between them; and the interposition of another body does not seem to prevent or even modify its action. This looks like action at a distance. Philosophers assert that no two

particles of matter actually touch each other; and if this be true, it appears that all action is necessarily at a distance, though in this case the distance would be inconceivably small. But this is debatable ground, and we leave it, simply remarking that, according to our present knowledge, the mutual action of two bodies implies an intervening medium of some kind.

*The Law of Universal Gravitation*, discovered by Sir Isaac Newton, is the most exact and far-reaching of all known laws of force. This law is: *The attraction between two particles varies directly as the product of their masses, and inversely as the square of the distance between them.* In reference to one particle, we would say that it attracts every other particle with a force which varies as its mass and inversely as the square of the distance between them, from which fact the law above given may be deduced. It follows from this law that the attraction of a homogeneous sphere upon a particle exterior to it is the same as if the entire mass were concentrated at the centre of the sphere; and hence the attraction of two homogeneous spheres for each other varies directly as the product of their masses, and inversely as the square of the distance between their centres. It may also be shown by this law that the attraction of a perfectly homogeneous spherical shell is the same upon a particle placed anywhere within it (Fig. 1117); and from this result it is easily shown that if the earth were a homogeneous sphere, the force of gravity would be zero at the centre, and would increase directly as the distance from the centre. By the aid of this law the spheroidal form of the earth and other planets is accounted for; the form of the orbits of the planets is determined; the action of the tides, the inequalities of the movements of the planets in their orbits, and many other interesting phenomena in astronomy, are explained.

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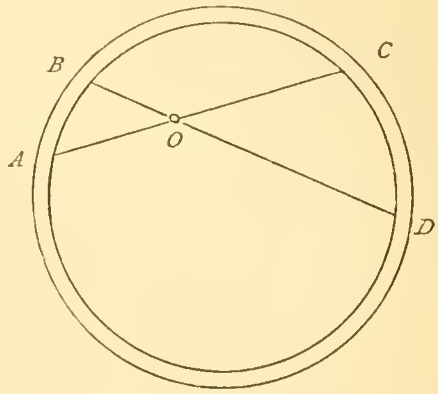


Some forces are repulsive in their action. The force with which two bodies repel each other, when one is positively and the other is negatively electrified, varies inversely as the square of the distance between them.

Weight is simply a measure of the action of gravity upon the body; or, more strictly speaking, it is a measure of the mutual attraction of the body and the earth. It is found that if a body be weighed with a spring-balance, it will weigh less at the equator than at high latitudes, and less on a high mountain than at its foot; and the weight thus determined shows that the force of gravity is different at different places. If the earth were a homogeneous sphere, the weight of a body would be the same at all points on its surface; but it is so flattened at the poles that the distance of the pole from the centre is about 13 miles less than that of the equator, and a body weighs correspondingly more at the poles than at the equator. The standard unit of weight in England and in the United States is the pound avoirdupois, and this is the weight of a certain piece of platinum kept by the proper officer for the purpose of preserving the standard. (See Measure, Standards of.) If any body be weighed by balancing it on a beam-scale with standard pounds, the body will weigh the same at all places, for the force of gravity will act equally upon both. By weighing bodies in this manner the quantity of matter in a given body compared with the standard becomes known.

Mass is quantity of matter. This is one of the most absolute quantities used in mechanics. It is in a certain sense independent of weight, or volume, or temperature; for it is supposed to remain the same whether it be placed at the centre of the earth, where it would have no weight, or on the surface of the earth, where it would have weight, or at a certain point between the earth and moon, where the attractive forces of these two bodies are equal, in which place it would have no weight; or whether in these different places it should be contracted or expanded, thus changing its volume; or whether its temperature should change: under all these conditions a certain mass is supposed to be constant. In measuring it, therefore, such a method must be used as will give a constant result. The method employed in mechanics is to divide the weight of the body by twice the distance through which the body would fall freely in one second at the place where it was weighed. In this way we have:

$$\frac{\text{Weight of the body}}{\text{acceleration of its fall}} = \text{the mass of the body};$$

the weight being in pounds and the acceleration in feet per second, for English measures. Another way is to assume an arbitrary quantity of matter as the unit of mass: then will the mass of any other body be found by dividing its weight by the weight of the unit of mass, both being weighed at the same place.

It is well to observe the perfect coexistence of force and matter; we know nothing of one without the other, and their separation is inconceivable.

Density relates to the compactness of matter. In mechanics it is the mass of a unit of volume. In physics it is sometimes used in the same sense as specific gravity. Both are equally good for giving the idea of compactness. According to the former, the density of a body is the weight of a unit of volume of the body divided by the acceleration due to gravity. For instance, the weight of a cubic foot of iron is, say, 450 lbs.; then will its density be $450 \div 32\frac{1}{6} = 14$ nearly. The *specific gravity* of the body is its weight compared with an equal volume of distilled water. A cubic foot of distilled water weighs, say, $62\frac{1}{2}$ lbs.; and hence the specific gravity of the iron would be $450 \div 62\frac{1}{2} = 7.2$. Since both methods are used, it is necessary to indicate by the context or otherwise which is intended. The density of the earth is very nearly $5\frac{1}{2}$ times that of distilled water.

Dynamic Measure of Force.—By the dynamic measure of force we mean a measure of the intensity of so much of the force acting upon a body as is instrumental in directly producing motion.

Forces of great intensity may act in contrary directions upon a body, thus partially or wholly neutralizing each other's effects, and producing little or no motion. Thus, when a locomotive draws a train of cars, a portion of the pulling force is directly neutralized by the resistance of the air, friction on the track, and other resistances of the train. If the pulling force exceeds the resistances, the excess will be the effective pulling force. When the resistances equal the pulling force, the motion becomes uniform. The force which produces motion is commonly called the *unbalanced force*, the true signification of which has already been explained. It is, according to Newton's second law, measured by the rate of change of the momentum. But the rate of change of the velocity is the acceleration; hence we have: Force = mass × acceleration. This measure of force was called by Gauss "the absolute measure of force."

*Illustration.*—If two equal sleds were connected by a string, and a boy were to pull on the first one with a constant force of 10 lbs., what would be the tension of the connecting string, supposing the sleds to be drawn on perfectly smooth ice? There being no frictional resistance, the tension will be caused by moving the masses; and since the force will be equally distributed throughout the masses, the tension of the connecting string will be 5 lbs. The motion will be the same as if a pull of 5 lbs. were applied directly to each sled. If the sleds were light, the acceleration (or speed, as the boy would say) would be great; but if the sleds were very massive, the acceleration would be small. The lighter the moving parts of an engine, the greater will be their speed for a given steam-pressure when no work is being done.

MOMENTUM is the product of the mass of a body into its velocity, and is often called quantity of motion. *It is a measure of the effect produced by a force in a given time*, and hence may properly be called *a time-effect*. If the force acts with a variable intensity, let the time be divided into portions so small that the intensity of the force during each interval of time may be considered constant; then the momentum will be the sum of the products of each force into the corresponding time. Momentum is not a force, nor the measure of force. The unit of momentum is the momentum of a unit of mass moving with a unit of velocity; and in English measures it is 1 pound of mass moving with a velocity of 1 foot per second.

WORK is the overcoming of a resistance continually recurring along the path of motion. This definition is drawn directly from the idea of work as performed by men, animals, and machines. But in treating of forces generally, it is found advisable to extend this definition as follows: A force is said to work when it moves its own point of application through space. Thus, if a man carries a weight up a ladder, he does a certain amount of work; and if he drops it when he gets to the top, gravity will do just the same amount of work in pulling it to the earth again; and when the body strikes the earth and is brought to rest, the body does the same amount of work in tearing up the earth that gravity did in pulling it down. A horse does work as he draws a load; rivers do work in wearing down their beds and banks; wind does work in blowing dust, driving ships, turning windmills, etc.; electricity does work in moving electrical machines (see ELECTRICITY); heat does work in expanding bodies, causing vapor to rise in the air, generating steam, etc. (see THERMO-DYNAMICS); in short, all the agencies on the earth which produce motion do work, for the bodies moved meet with resistances. Mere motion is not work; so that, if the planets move in void space, they do no work. Neither is mere pressure work; motion as well as pressure is necessary.

In order to find a measure for work, we observe that if a man does a certain amount of work by carrying a load one mile, he does twice the work by carrying it two miles, and so on for any number of miles. Similarly, if a locomotive does a certain amount of work in drawing a train one mile, it does twice the work in drawing it two miles, and so on, the resistance being constant. The same is true for any other power or agent. Hence the amount of work, the resistance remaining constant, varies directly as the space over which the force works. It is also evident that if the resistance be doubled, twice the work will be done in the same space; and if it be made threefold, three times the work will be done, and so on. Hence the total work done varies as the resistance and space jointly. If $U$ represent the work, $F$ the constant force doing the work acting along the path of motion, and $s$ the space over which $F$ acts, then we have, according to the definition, $U = F \times s$. The work done does not depend upon the magnitude of the load moved, but upon the resistance overcome. A horse may do the same work in drawing a small load over a rough road as in drawing a large load over a smooth road. An engine on an improperly constructed vessel may do much more mechanical work in driving the vessel from New York to Liverpool than another engine on a larger but properly constructed vessel in driving its vessel the same distance. The work done is independent of the time. A man does only a definite amount of work in carrying a weight from the cellar to the garret, whether it be done in one minute or one hour. The one who does a given amount of work in the shortest time is the most *efficient*, and may be the most profitable; but that involves other elements than mere work. If a boy is required to draw all the water out of a cistern, he will, in performing the task, do a certain amount of mechanical work; and the work will be done when the cistern is emptied, whether it be done in an hour or a day. It is true that time is required in order to do work, and all that is meant by work being independent of time is, that the time is not limited by the conditions of the problem. The unit of work is the work of raising 1 pound 1 foot high, and is called a *foot-pound*.

To determine the work done by an animal or machine, it is necessary to measure the force exerted by the agent and the space through which it acts. In many cases the force is variable, and it is desirable to have an automatic record of the force and the corresponding space. The force is measured by some kind of a spring-balance, called a dynamometer (see DYNAMOMETER), placed between the power and resistance. An index indicates the pounds of pull; and by having a piece of paper pass under the end of the index, having a rate of movement proportional to that of the working agent, a line may be traced which will enable one to determine the work done. For instance, if the resistance be constant, the figure formed will be a rectangle, $A\ B\ C\ D$, Fig. 1118, in which the bases will rep-

resent the space according to some scale, and the altitude $F$ the force according to some other scale. But if the force is not constant, a curved or broken line will be traced, Fig. 1118 A, the base of which will represent the space, and the perpendiculars $C\,M$, $N\,D$, etc., from which to the curved

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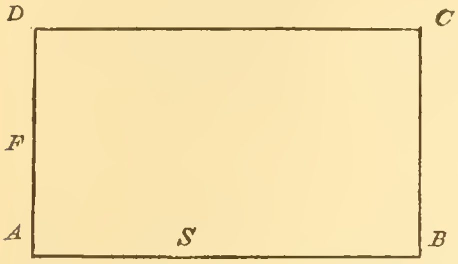
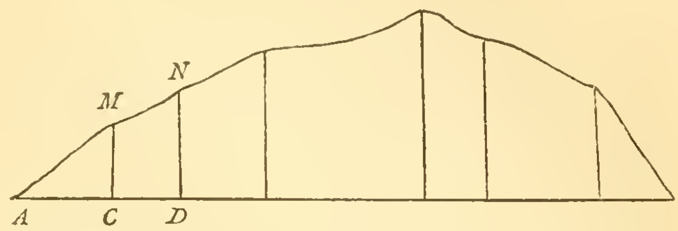
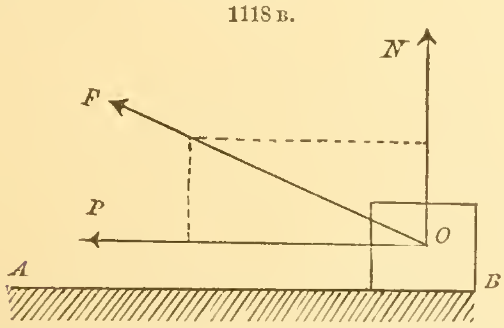



1118 A.

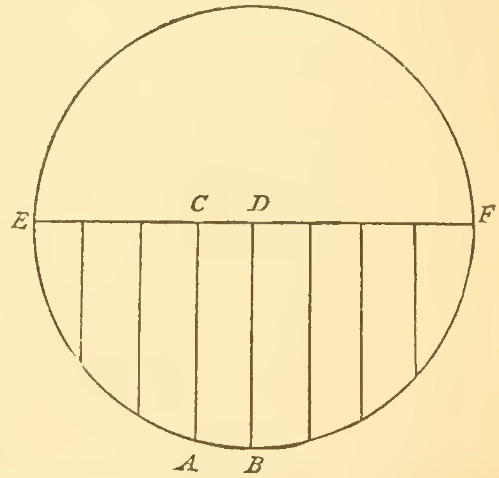



line will represent the resistances at the corresponding point of the path. The area of the figure thus found will represent the work in foot-pounds. The area may be found to any degree of approximation by dividing the figure into trapezoids so small that the portion of the curved line between any two consecutive ordinates may be considered as straight. If the force acts at an angle with the path along which the body moves, we find how much force is required to pull the body when it acts parallel to the path. Let $P$, Fig. 1118 B, be the latter force; then, to find the work which it can do, multiply the force in pounds by the space in feet over which the body is drawn by this force. When the force is inclined upward, it lifts upon the body, so that it may not require as much to draw the body along as when it acts horizontally. If we know the force and the angle at which it is inclined upward, we may find how much it lifts upon the body, and how much it pulls along, as follows: Draw the line $O\,F$, making the same inclination upward as the actual force, and let $O\,a$ on the scale represent the number of pounds in the force. Draw $O\,b$ horizontal and $a\,b$ vertical; then will $a\,b$ represent the lift on the load and $O\,b$ the horizontal pull.

1118 B.




1118 C.




*Example.*—Let the force be 100 lbs. pulling upward at an angle of 30°. Let $O\,a = 1$ inch; then it will be found that $a\,b$ will $= \frac{1}{2}$ inch and $O\,b = 0.86$ of an inch, and the upward lift will be $\frac{1}{2}$ of $100 = 50$ lbs., and the horizontal pull will be $0.86 \times 100 = 86$ lbs. If the lift on the load should reduce the resistance, so that it would draw easier than before, there might be a gain in drawing at an angle with the path; but if it did not diminish the resistance, there would be a loss. For if the pull be 100 lbs. drawn over a space of 50 feet, the work would be $100 \times 50 = 5{,}000$ foot-pounds; but when it draws at an angle of 30°, we see that the horizontal pull is 86 lbs., and the work will be $86 \times 50 = 4{,}300$ foot-pounds.

In machinery the path described by a working point may be much longer than that described by the force. Thus, in a steam-engine, let $E\,F$, Fig. 1118 C, represent the stroke of the piston, $D$ the centre of the crank, $D\,B$ the length of the crank, and $E\,B\,F$ the circumference described by the extremity of the crank. The diameter $E\,F$ will equal the stroke of the piston. To find the work done by the steam in driving the crank-pin $B$ around the circumference of a circle, we divide the circumference into small parts, and draw lines through the points of division perpendicular to the diameter $E\,F$. In passing from $A$ to $B$, Fig. 1118 C, the path is along the arc, but the force of the steam is along $C\,D$; and while the point is moving from $A$ to $B$, the piston will have moved a distance equal to $C\,D$; therefore the work done by the steam will equal the total steam-pressure upon the piston multiplied by $C\,D$, and similarly for all the other arcs. Hence the total work done in driving the point $B$ around a semi-circumference will be the steam-pressure multiplied by the diameter $E\,F$, which is the same as the pressure multiplied by the length of the stroke of the piston. Therefore, we conclude, if friction be discarded, that *no work is lost in changing from reciprocating to rotary motion;* and that the piston, crank, and fly-wheel are well adapted to each other for transmitting work.

Work is divided into *useful* and *prejudicial*. That is useful which produces the thing desired, as the production of flour from wheat, the making of a tool from steel, etc.; and that is prejudicial which wears out machinery or produces damage, as the friction of the axles of machinery, the wearing away of the beds and banks of streams, the wearing out of the rails on a railroad, etc. Prejudicial work always accompanies useful work, and it is not easy to draw a definite line between them; but we know that, in point of economy, it is desirable to reduce the former as much as possible.

When the motion is uniform, we know that the space over which a body moves is the product of

the time by the velocity. If, now, two machines work at different rates, the ratio of work which they can do in a given time will be directly as their velocities. Thus, if one moves at the rate of 4 miles an hour and the other at the rate of 8 miles an hour, then the latter goes twice as fast as the former, and in two hours it will go twice as far, and so on for any number of hours. Therefore, in order to determine the efficiency of machines, it is only necessary to determine their rate of doing work. This is called mechanical power by some writers, dynamic effect by others, and simply power by others. It implies the ability of an animal or machine to do work at a certain rate, and may be called *work-rate.* Its value is found by multiplying the force in pounds by the velocity in feet per minute. The unit of power is 1 *horse-power*, which is equivalent to raising 33,000 lbs. 1 foot per minute. To find the horse power of a machine, find its mechanical power per minute, and divide by 33,000.

*Examples.*—1. A spring-balance being placed between the evener and a plough, it is observed that a span of horses pull with a constant force of 200 lbs. in drawing the plough at the rate of 2 miles per hour: what horse-power is expended in working the plough? First find the velocity in feet; it will be $2 \times 5{,}280 = 10{,}560$ feet per hour, and $10{,}560 \div 60 = 176$ feet per minute; hence the work per minute will be $200 \times 176 = 35{,}200$ foot-pounds, which, divided by 33,000, gives $35{,}200 \div 33{,}000 = 1.06$ horse-power.

2. A train of cars whose weight is 300 tons is drawn at the rate of 40 miles per hour, if the friction of the train is 8 lbs. per ton: required the horse-power expended by the engine. *Solution:* The resistance will be $300 \times 8 = 2{,}400$ lbs. The velocity of 40 miles per hour will be $40 \times 5{,}280 = 211{,}200$ feet per hour; and the velocity per minute will be $211{,}200 \div 60 = 3{,}520$ feet. The work per minnte will be $2{,}400 \times 3{,}520 = 8{,}448{,}000$ foot-pounds, and the number of horse-power $8{,}448{,}000 \div 33{,}000 = 256$.

Energy is a term used to express the amount of work stored in a body. Thus, we speak of the energy of a moving body, energy in steam, solar energy, heat energy, etc. The term includes all kinds of material activities in nature. *Kinetic energy* is the energy of a moving mass. The energy of a moving body is equal to the work expended in producing the motion; the body stores the energy as the motion is produced, and parts with it whenever it meets with a resistance. The expression $\frac{1}{2} M v^2$ is the measure of the kinetic energy of the body, and equals the amount of work which the body will do in being brought to rest. This was formerly called the living force by some writers, while others called $M v^2$ the living force; either of which may be used, provided only that it is always used in the same sense in any particular problem. It varies as the square of the velocity of the moving body. If a ball with a velocity of 10 would penetrate the earth 2 feet, then with a velocity of 20 it would penetrate 4 feet, the resistance being uniform. This principle at first appears paradoxical, but it will be clear when it is observed that, in order to produce twice the velocity, the force must act through 4 times the space. In the case of falling bodies, if the times are as 1, 2, 3, 4, etc., the velocities will also be as 1, 2, 3, 4, etc., and the spaces as 1, 4, 9, 16, etc. Hence the spaces are as the squares of the velocities, and the same law must hold in overcoming the velocity by a constant resistance.

In order to destroy the energy of a body, a force must act against it. If there were a hole through the earth, and a body were dropped into it, gravity would constantly pull upon the body as it moved from the surface to the centre, at which point the velocity would be greatest. After the body passed the centre gravity would pull against it, making it go slower and slower; but gravity would not stop the body until it had opposed the forward motion of the latter as much as it had previously accelerated the same. The body would, therefore, if in a vacuum, go from one side of the earth to the other; then it would return, and thus move to and fro like the oscillations of a pendulum, requiring about 42 minutes to go from surface to surface. The action is much the same as if one end of a rubber string were attached to the body, and the other end fastened at the centre of the earth. The string would pull the body toward the centre constantly, but with a diminishing force; and after the body passed the centre the string would pull harder and harder against it until it finally stopped.

*Examples.*—1. If a ball whose weight is 2 lbs. have a velocity of 150 feet per second, how far will it penetrate the earth if the resistance is constant and equal to 50 lbs.? Here we have $50 \times s = \frac{1}{2} \frac{2}{32\frac{1}{6}} (150)^2$, which reduced gives over 14 feet.

2. If a train of cars whose weight is 60 tons moves with a velocity of 40 miles per hour, how many miles will it move before being brought to rest by friction, friction being 8 lbs. per ton, no allowance being made for the resistance of the air? In the solution of this example the tons should be reduced to pounds, and the velocity to feet per second; hence we have $F = 8 \times 60$, $M = \frac{60 \times 2000}{32\frac{1}{6}}$, $V = \frac{40 \times 5280}{60 \times 60}$ feet per second. Then, $\frac{1}{2} M V^2 = \frac{60 \times 2000 \times 40^2 \times 5280^2}{2 \times 32\frac{1}{6} \times 60^2 \times 60^2} = 6{,}386{,}680$ foot-pounds.

Dividing this result by the force $= 8 \times 60 = 480$ lbs., will give the number of feet required, and that divided by 5,280 feet will give the number of miles; hence we have $\frac{6386680}{480 \times 5280} = 2.52$ miles.

The Mechanical Equivalent of Heat.—Energy also exists in the motion of the particles of bodies. Heat is not a material, as was once supposed, but consists of the rapid vibrations of the particles of the body in which it exists; and all pressure, such as steam-pressure, atmospheric pressure, and the pressure between any two bodies, is supposed to be due to the striking of particles against the surface pressed. The discovery that the heat in a body is capable of doing a definite amount of work is due to Dr. Joule of England, although the fact that heat was a form of energy was shown previously by Count Rumford, as early as the year 1798. He observed that boring a

cannon with a blunt tool produced a high degree of temperature, and in one experiment so much heat was generated by the friction as to cause water to boil. But Dr. Joule, during the years from 1840 to 1843, by elaborate and careful experiments, proved that the amount of heat in a body could be expressed in terms of a certain amount of work; and that the heat necessary to raise 1 pound of water 1° F. was equivalent to raising a body whose weight is 772 lbs. through a vertical height of 1 foot. This quantity of work is called *the mechanical equivalent of heat*, a term first introduced by Dr. Mayer of Heilbronn in the year 1842. Dr. Joule experimented upon different substances and in different ways, but the results of the experiments differed by only a few foot-pounds. The formula in French units is: The heat necessary to raise 1 kilogramme of water 1° is equivalent to the work of raising 424 kilogrammes vertically 1 metre. The establishment of this principle led scientists to investigate the matter in regard to other agents, such as electricity, magnetism, light, and everything which in any way affects our senses, or which operates in the economy of nature; and although it has not been possible to trace the energies from one phase to another in such a manner as to measure the exact equivalents, yet it is found that to produce energy in any form there is a loss of energy in the agent producing it. For instance, in electric machines, now used for producing light, the horse-power necessary to produce a light equivalent to a given number of wax candles of given size can be measured. Electricity may be generated by the expenditure of a certain amount of work, and similarly for other active agents. Such experiments and extended observation have led to the establishment of the following

Laws of the Conservation of Energy.—1. *The total amount of energy in the universe is constant;* from which it follows that energy is indestructible. 2. *The various forms of energy may be converted the one into the other.* These laws are believed to be as extensive and as rigidly exact as the law of universal gravitation. They are made the foundation of many investigations in modern physics. According to them, a perpetual-motion machine is an impossibility; for the energy of the machine consists of that which is put into it from an external source; in other words, it has no power within itself to create energy; and hence, if there is any external resistance, such as friction, its energy will be constantly consumed in overcoming that resistance, and it will come to rest when its energy is all expended. The energy of the machine will have passed into surrounding bodies. In the present state of science, it is impossible to change a given amount of heat into an equivalent amount of mechanical work, much being lost in the transformation. At every attempt to change energy from one form to another, there appears to be a degradation of energy, that is, a production of an energy of an inferior form so called; or, more properly, there is apparently a *dissipation* of energy. Reasoning in this way, many modern writers have predicted that ultimately the total energy of the universe would become uniformly diffused throughout space in the form of heat, and the universe thus become mechanically dead. But as we are unable at present to include all the elements of the problem, and much less to trace their influence throughout the circuit of their action, the basis of the argument is necessarily hypothetical. On the other hand, if we assume that the ultimate condition of the universe is that of perfect elasticity, it is certain that, if any amount of visible energy is put into the universe, that amount must forever exist; and hence, according to this hypothesis, the universe can never become mechanically dead. Energies work only as they are transmitted from one condition to another; and to secure this transmission there must be a non-equilibrium of energies. If there be an effort in nature to produce a state of universal equilibrium, its effect is only to reduce that which was above the average to an energy equally below it, and that which was below to that equally above, and so on; just as the waves of the sea at one point rise first above the general level, and then below; or like the oscillations of the pendulum, first descending to the lowest position, then rising to the same height as before on the opposite side, and so on. We are not, however, able to realize the condition of *perfect* elasticity in physical experiments, and hence this reasoning is also hypothetical.

Potential Energy implies a latent energy. To illustrate, if a stone *rests* on the top of a tower, it has no energy; but in reference to some point below, it has the ability to do a certain amount of work when its support is removed. Similarly, the steam simply inclosed in a boiler does no work; but when a hole is made in the boiler, permitting the steam to escape, it rushes out and does work in various ways, and, passing through an engine, may be made to do mechanical work. An elastic rod held in a bent position does no work; but if the force which holds it be removed, it will, by virtue of the motion which results, be capable of doing work. Potential energy has no absolute unit; its value is determined only in reference to some fixed condition. Thus, in regard to the stone on the tower, we say that, in reference to a point 10 feet below, its potential energy will be 10 times the weight of the body; and if the point of reference be 20 feet below, it will be 20 times the weight, and so on. If it actually falls 20 feet, the kinetic energy of the body will be 20 times the weight, so that all of the potential energy will have been changed to kinetic. Similarly, in regard to steam-pressure, if the point of reference be that of atmospheric pressure, the potential energy will have one value; and if the reference be that of a perfect vacuum, it will have another value. The point of reference having been fixed, we have this important principle: The sum of the potential and kinetic energies remains constant. This is equivalent to saying that work which a force has done added to that which it is capable of doing equals that which it was capable of doing at first. If the stone on the tower be 100 feet from the ground, its potential energy will be 100 times its weight; but if it fall 10 feet, the kinetic energy stored in the body will equal 10 times its weight, and the potential energy in reference to the earth 90 times its weight, and therefore both together will be 100 times its weight; and so on for any amount of fall less than 100 feet. If the tower were 150 feet high, the reasoning would be the same.

Centrifugal and Centripetal Forces.—*The centrifugal force*, in reference to circular motion, is defined as a force acting directly away from the centre, and *centripetal force* as one acting directly toward the same centre. If a body is made to revolve in the arc of a circle, there must necessarily

be a force applied to it at every point of its path to deflect it from a tangent to the path. If a string be attached to the body and to a fixed point, the constant pull of the string will cause the body to travel in the arc of a circle. The pull of the string represents the centripetal force acting toward the centre of the circle. But if we examine the pin to which the string is attached at the centre of the circle, it will be seen that the body is *apparently* pulling on this pin. This is the centrifugal force, acting directly away from the centre. The two forces are equal and directly contrary in their action. If the string be cut at any point and forces applied at each end where it is cut, producing the same tension as before, it will be observed that these forces must be equal and opposite. The force acting upon that part of the string attached to the body will pull toward the centre, and will be centripetal; while the one acting on the piece attached to the pin at the centre will act directly away from it, and will be the centrifugal force. Like the action of a force between bodies, where the action is upon one body and the reaction directly contrary upon the other body; so here, the centripetal and centrifugal forces are an action between bodies, one of which acts upon the revolving body toward the centre, the other upon the central body away from the centre. They never exist singly; one always accompanies the other. Both never act upon the same body at the same time. When a boy swings his sling, he is conscious of a pull upon his hand; but it is no more correct to say that the revolving body pulls, than it is to say that his sled or wagon pulls on his hand as he draws it; and it is just as proper to say one as the other. In both cases the body is inert, and the active agent exists in the hand, or even further back if we desire to trace it. In the case of a train of cars running around a curve, the rails on the curve force the train constantly toward the centre, and force is developed between the rim of the wheels and the rail, which force acts equally in contrary directions; that acting upon the wheels toward the centre is centripetal, and the other, acting upon the rails, is centrifugal. By elevating the outer rail properly, gravity is made to take the place of the centripetal force, and the resultant pressure may be directly upon the face of the rails.

In the solar system, the attraction of the sun upon any planet is the centripetal force upon that planet, and the attraction of the planet upon the sun is the centrifugal force upon the sun due to that planet. The centrifugal force upon the matter of the earth due to its rotation on its axis acts against gravity at all places except at or near the poles, thereby making the matter on the equator less heavy than it otherwise would be; and this causes the matter to be elevated at the equator and depressed at the poles, giving to the earth a spheroidal form. Bodies on the equator now weigh less than they otherwise would by about $\frac{1}{289}$ of their present weight; and if the earth revolved in $\frac{1}{17}$ of its present time, or in say 1 hour and 25 minutes, they would weigh nothing. The centrifugal force diminishes from the equator toward the poles nearly as the square of the sine of the latitude. The form which the earth ought to assume for equilibrium, on the hypothesis that it was once in a fluid state, or that its density varies according to an assumed law and subjected to known laws, has been the subject of profound analysis by such mathematicians as Huygens, Newton, Laplace, Ivory, and others; from which it appears that one of the theoretical forms agrees nearly with the actual form. The forces on the surface of the earth are now in equilibrium, so that there is no more tendency for bodies to move toward the equator on account of the centrifugal force than in any other direction. All the planets are known to be spheroidal, their equatorial diameter being greater than their polar axis.

It is not correct, *strictly* speaking, to say, in reference to the revolving body, that the centrifugal force tends to throw it away from the centre; for no such force acts upon the body. If the centripetal force be destroyed, the centrifugal force is destroyed at the same time; and the body, in obedience to the *first law*, goes off on a tangent, and not radially outward. But the expression need not be entirely condemned, for it is a popular and convenient term to express what *appears* to be true; just as we say "the sun rises," to express an appearance, whereas the sun in fact does not move. Thus, the common expression, "The centrifugal force caused the fly-wheel to burst," strictly means that the arms of the wheel were not sufficiently strong to compel the rim to move in a circle, and in their effort to do it the arms were broken. But the cause of the breakage is as well understood from the common expression as from a scientific explanation of it.

It is found that the centrifugal force varies directly as the square of the velocity and inversely as the radius, and directly as the mass of the body; hence we have:

$$\text{Centrifugal force} = \frac{\text{weight} \times (\text{velocity})^2}{32\frac{1}{6} \times \text{radius}}.$$

*Examples.*—1. The arms of a fly-wheel will each sustain a pull of 45,000 lbs.; the weight of the rim between two arms is 1,000 lbs.; the radius of the wheel is 4 feet; and the wheel makes 500 revolutions per minute: will it burst on account of this velocity? The velocity in feet per second will be $\frac{3\frac{1}{7} \times 4 \times 500}{60} = 101$ feet; hence we have:

$$\text{Centrifugal force} = \frac{1000 \times (101)^2}{32\frac{1}{6} \times 4} = 80{,}000 \text{ lbs. nearly},$$

which is nearly twice the strength of the arm; hence it would burst.

2. Would it burst at 300 revolutions per minute? For this we find:

$$\text{Centrifugal force} = \frac{1000 \times (60\frac{1}{2})^2}{32\frac{1}{6} \times 4} = 28{,}000 \text{ lbs. nearly},$$

which is a little more than one-half the strength of the arm, and hence it would not burst; but in practice the arms should be 6 or 8 times as strong as the centrifugal force.

*Works for reference* on dynamics will be found classified under MECHANICS. DE V. W.

DYNAMITE. See EXPLOSIVES.

DYNAMO-ELECTRIC MACHINES. Apparatus for the production and collection of induced currents of dynamic electricity; or, more strictly, for the transformation of mechanical work into electricity. The term "dynamo-electric machine," while it may well include all apparatus based on

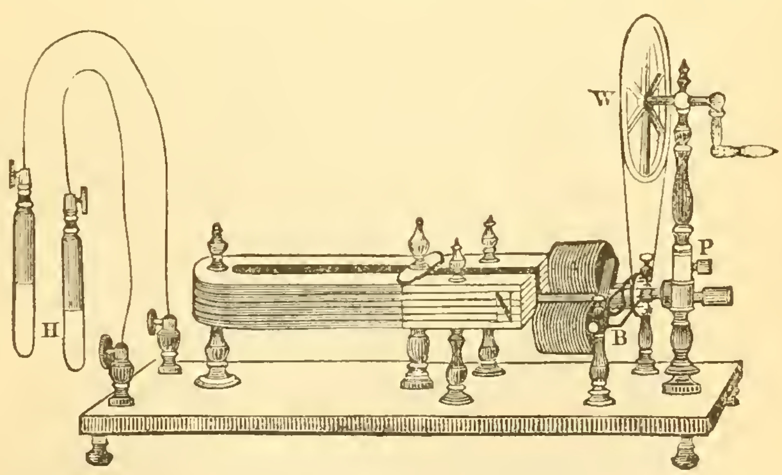
the principle outlined below, is by some authorities confined to devices in which electro-magnets are substituted for permanent magnets, the term "magneto-electric" being applied to contrivances embodying the latter. For the sake of classification, this distinction will here be adopted. The principles on which all such machines are constructed may be summed up briefly. For more detailed discussion, reference may be had to the various treatises on electricity noted under that heading.

If a magnet be suddenly placed within a coil composed of insulated wire, an induced current will be set up in the wire of the coil, provided its ends are conductively connected. As long as the magnet remains at rest, no induced current is manifested; but if it be suddenly removed, another induced current arises in the coil, the direction of which is opposite to that of the former one. The direction of both these currents, which are in all cases opposed to each other, depends upon the polarity of the end of the magnet which is turned toward the coil. By causing a magnet and a coil of wire alternately to approach and withdraw from each other in rapid succession, momentary induced currents, flowing alternately in opposite directions, are produced in the wire. These currents are, besides, of very short duration, but in other respects they possess all the qualities of ordinary battery currents. The effect is the same when the magnet is made to revolve in such a way that its poles rapidly pass the ends of soft-iron bars surrounded with the coil, currents being as before caused in the coil; and, so far as the result is concerned, it is immaterial whether the magnet moves past the soft iron of the coil or the soft iron moves past the magnetic poles. In practice, however, as the soft-iron bar and coil may be made very light and be easily arranged, and as other advantages at the same time are secured, this portion is made movable; and hence the modern dynamo- or magneto-electric machine consists of a fixed magnet and a moving "armature," this last name being applied to the coil and its core.

In Pixii's machine, one of the first constructed, a permanent horseshoe magnet placed vertically, its poles uppermost, was caused to rotate before the poles of an electro-magnet disposed from a frame above. At each semi-revolution of the magnet a current was caused in the wire of the electro-magnet, which was alternately direct and inverse. In order to change this alternating current into one of continuous flow, the *commutator* was contrived. This device is one of the most important portions of all machines producing alternating currents, and its construction is exhibited in Fig. 1119. Let $A$ and $B$ represent the halves of a cylinder completely isolated from each other by the non-conducting material $F$ $G$, and each connected with the poles of any voltaic battery. So long as the cylinder remains at rest, the rubbing-pieces or wipers $C$ and $D$, and the conductors $H$ $J$ attached thereto, will receive a direct current; but when the cylinder is turned on its axis, and at each semi-revolution, the current collected by the wipers will change, as already stated, in direction. If the cylinder $A$ $B$ be combined with the axle of an induction machine, so that the axle or shaft may turn with or without the cylinder, and if the semi-cylinder $A$ be connected to one coil of the electro-magnet and the cylinder $B$ to the other, exactly the opposite effect will be produced to that which took place when the cylinder was connected with a voltaic battery. The cylinder remaining fixed and the machine rotating, alternating currents will be caused in the conductors $H$ $J$; but when the cylinder $A$ $B$ participates in the movement of the machine, the collected currents will always be of the same direction, the arrangements being such that the current developed in the electro-magnet changes direction when the wipers $C$ and $D$ pass from one semi-cylinder to another. The forms and

1119.


1120.



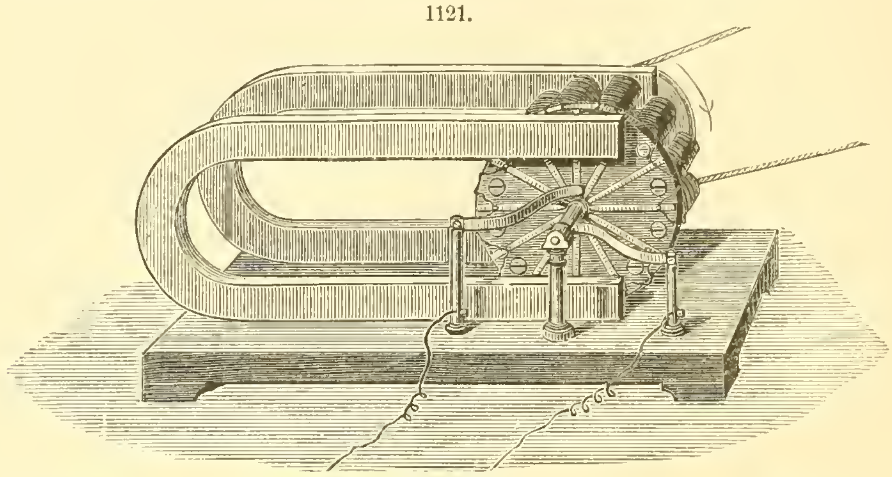

combinations of commutators vary greatly, but the foregoing sums up their fundamental principle—namely, to present the inverse poles of a circuit to the rubbing-pieces at each inversion of the current in the machine. It should be added that when the wipers pass from one cylinder to another, very intense sparks are often produced, which rapidly cause the deterioration of the apparatus. This has proved the source of failure in many otherwise excellently contrived machines, and to its obviation the attention of inventors is directed.

Magneto-electric Machines.—Pixii's machine, involving as it did a massive permanent moving magnet, and hence being open to many disadvantages, gave place to Saxton's machine, in which a horizontal electro-magnet turned before the poles of a horizontal permanent magnet, and to Clarke's machine, wherein the same idea was embodied, the magnet being placed vertically on a support and the electro-magnet arranged to turn laterally beside it. Saxton's arrangement is that shown in Fig. 1120. From the wheel $W$ a band is extended around a smaller wheel or pulley to be turned thereby.

The upper part of the pillar $P$ slides into the lower part, and admits of being fixed higher or lower by the binding-screw $P$, so as to tighten the band as desired. A U-magnet $N$ is fixed horizontally with its two poles as near to the ends of the armature $B$ as will allow the latter to revolve without touching them. The armature is made of a piece of soft iron, bent twice at right angles to resemble also the shape of the letter U. Around each of its legs is wound a helix of fine wire coated with thread. This piece of iron, with its environing coils of insulated wire, is fixed upon an axis extended from the pillar $P$ to another pillar erected between the poles of the magnet. This axis is caused to revolve rapidly by the band from the multiplying wheel $W$.

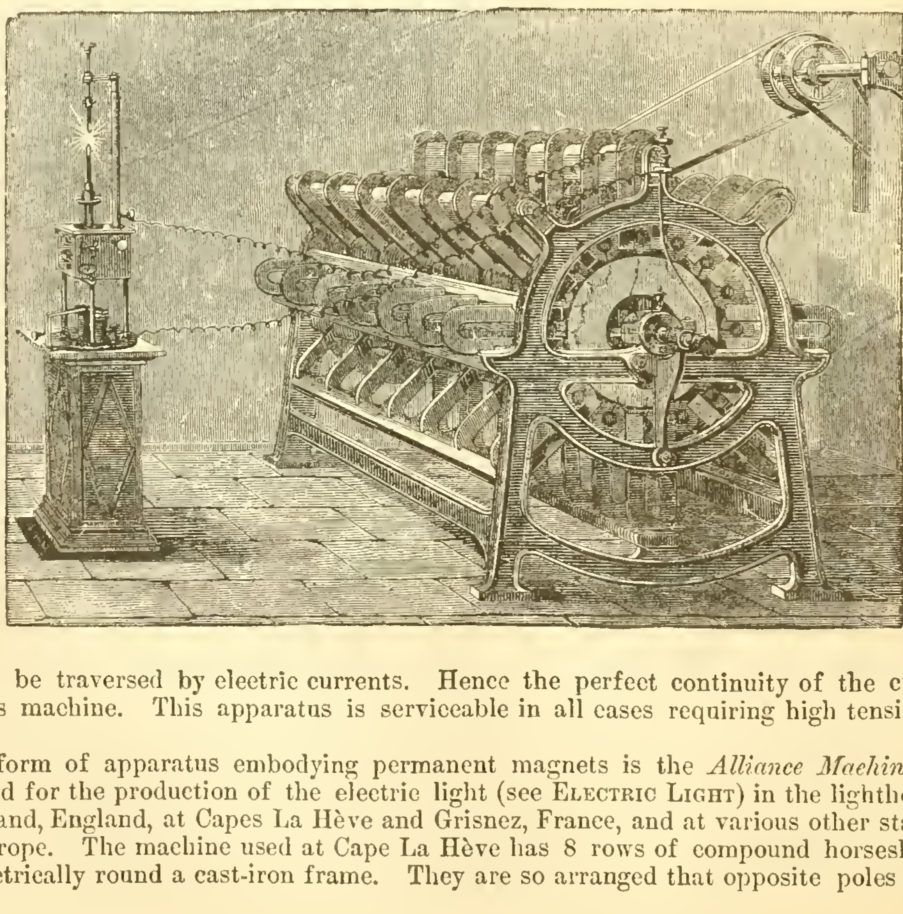
*Niaudet's Machine.*—Fig. 1121 is simply a multiple Clarke machine, inasmuch as the electro-magnets rotate laterally beside and between the permanent magnets. It possesses the advantage of

1121.



requiring no commutator in order to produce continuous currents. Its construction is as follows: A circular disk is mounted on a horizontal axis; 12 bobbins are inserted in this disk in such a way as to resemble the floats of a paddle-wheel. The bobbins are connected together like so many elements of a galvanic battery, and thus they form one continuous length. When in motion, all the bobbins on the left are traversed by a current in one direction, and all those on the right by a current opposite in direction but equal in volume to the former. The apparatus might not inaptly be compared to two distinct batteries consisting of 6 elements, each connected together for tension. The uniting of these two batteries for quantity is effected by two metallic springs attached to two small uprights which are the terminals of the machine. Twelve strips of copper are disposed radially, and to them are attached the two adjacent ends of every pair of bobbins. The metallic springs are virtually current-collectors; and as they are always in contact with several of the radial strips, they

1122.

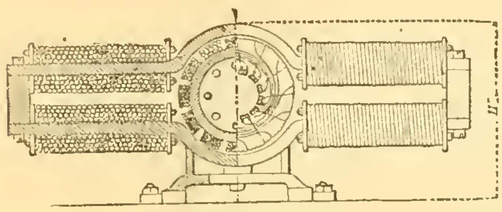


must always be traversed by electric currents. Hence the perfect continuity of the current developed by this machine. This apparatus is serviceable in all cases requiring high tension but small quantity.

Another form of apparatus embodying permanent magnets is the *Alliance Machine*, Fig. 1122, which is used for the production of the electric light (see Electric Light) in the lighthouses at the South Foreland, England, at Capes La Hève and Grisnez, France, and at various other stations in the north of Europe. The machine used at Cape La Hève has 8 rows of compound horseshoe magnets fixed symmetrically round a cast-iron frame. They are so arranged that opposite poles always suc-

ceed each other, both in each row and in each circular set. There are 7 of these circular sets, with 6 intervening spaces. Six bronze wheels, mounted on one central axis, revolve in these intervals, the axis being driven by steam-power transmitted by a pulley and belt. The speed of rotation is usually about 350 revolutions of the axis per minute. Each of the 6 bronze wheels carries at its circumference 16 coils, corresponding to the number of poles in each circular set. The core of each coil is a

1123.



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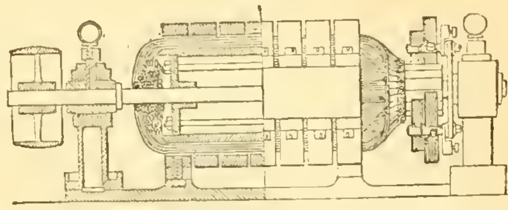
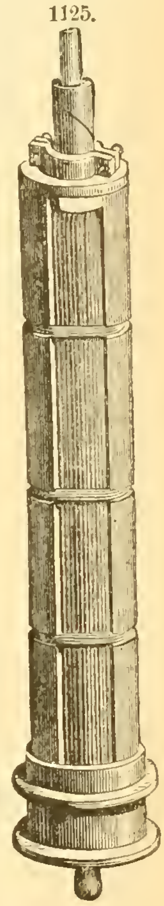


cleft tube of soft iron, this form having been found peculiarly favorable to rapid demagnetization. Each core has its magnetism reversed 16 times in each revolution, by the influence of the 16 successive pairs of poles between which it passes; and the same number of currents, in alternately opposite directions, are generated in the coils. The coils can be connected in different ways, according as great electromotive force or small resistance is required. The positive ends are connected with the axis of the machine, which thus serves as the positive electrode; and a concentric cylinder, well insulated from it, is employed as the negative electrode. This machine is large and cumbrous, being 5 feet 3 inches long, 4 feet 4 inches wide, and 5 feet high; it weighs about 2 tons. Its illuminating power, when driven at a speed of from 350 to 400 revolutions per minute by a steam-engine, with an expenditure of somewhat over 3 indicated horse-power, is about that of 2,500 standard sperm candles per hour. Its use may be said to have passed away, it being retained (1879) only in the lighthouses above mentioned.

1125.



Dynamo-electric Machines (proper).—In 1867 the discovery was made almost simultaneously by Dr. Siemens, by Sir Charles Wheatstone, and by Mr. S. R. Varley, that if an induction coil be made to revolve in front of a soft-iron electro-magnet, instead of before a permanent magnet, as in the earlier machines, the small amount of residual magnetism always latent in the iron, especially if it has been once magnetized, causes feeble currents to be induced in the coil; and if these currents, or a portion of them, are sent round the iron magnet, i. e., into the wire surrounding it, the magnetization of the iron is increased. This again produces a proportionate increase in the induced currents in the coil; and thus, by a series of successive mutual actions, intense magnetization and very powerful currents are produced. This discovery, by adding considerably to the power of the machines, led to a corresponding diminution in their bulk, and also in their costliness. Among the best known devices of this class is

*The Siemens Machine*, Figs. 1123, 1124, and 1125. This consists of an induction coil, with the convolutions of the copper wire wound lengthwise with the cylinder, in the form known as the modified Siemens armature, Fig. 1125. This coil is made to revolve by mechanical means between curved iron bars, which are the prolongation of the cores of large flat electro-magnets placed on either side of the induction coil; the north pole of the system being midway between the two upper electro-magnets and directly over the axis of the coil, and the south pole in a similar position below the axis upon the bar between the lower magnets. The portion of the coil which during its revolution is traveling downward has (with the above arrangement) positive currents induced in it; while the ascending half of the coil is subjected to negative currents, but both in the same direction as regards circuit. The arrangement of the poles may, however, be exactly the reverse of the above. Sections of a machine of about 6,000 candle-power are given in Figs. 1123 and 1124.

*Table showing Sizes and Capacities of the Siemens Machine.*

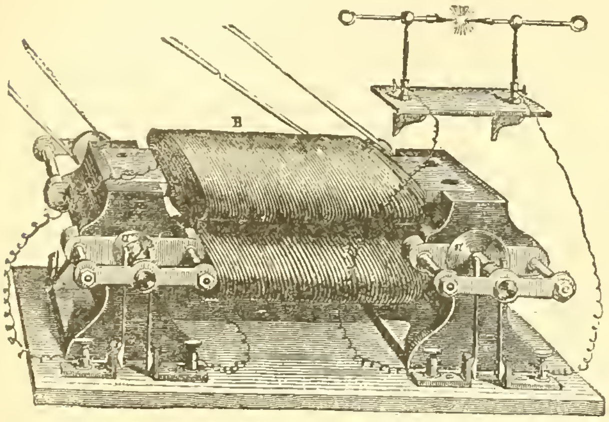
| NUMBER. | Revolutions per Minute. | Illuminating Power, standard Candles. | Actual Horse-Power required. | Weight, lbs. |
|---|---|---|---|---|
| I. | 850 | 1,200 | 2 | 250 |
| II. | 650 | 6,000 | 4 | 375 |
| III. | 360 | 14,000 | 8 | 1,150 |

*The Ladd Machine*, Fig. 1126, is largely dependent on the reaction principle above explained. It consists of two separate electro-magnets *B*, consisting of slabs of soft iron surrounded with insulated wire as shown. The supporting frames are bored out to take two Siemens armatures, *a a*. The current from the armature on the left is made to pass around the electro-magnets *B*. The current from the other armature is utilized to produce the electric light as shown. The action of the machine is as follows: A voltaic current is passed once for all through the coils *B B*. This magnetizes the soft-iron slabs, which forever afterward retain a small portion of their magnetism. If, then, the armatures are put in motion by bands as shown, a feeble electrical current will be set up in the armatures; but the current from the armature *a* on the left running round the magnets makes them much more powerful than they were originally. They in their turn react more forcibly on the armatures,

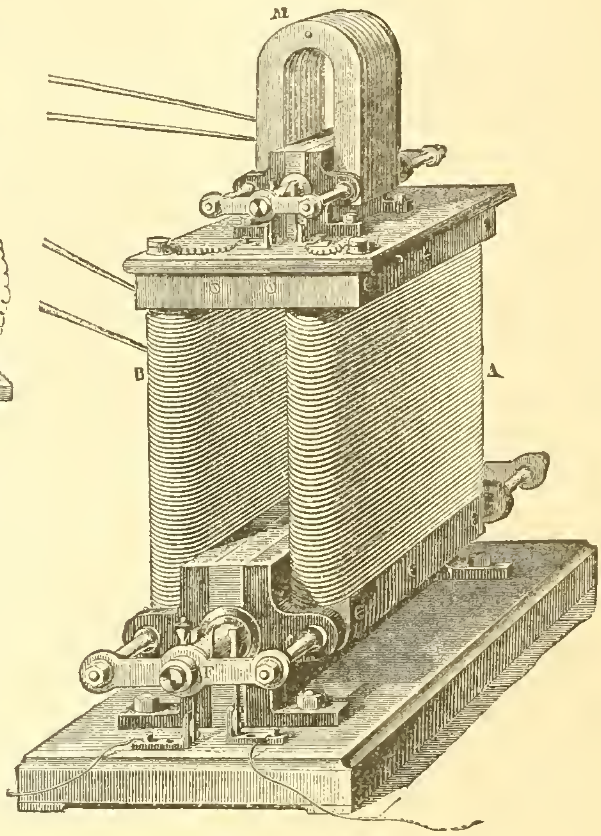
and so the magnets go on reacting on themselves until very large quantities of electricity are produced. Thus, a machine shown by Mr. Ladd in Paris in 1867 had plates only 24 inches long by 12 inches wide, and was quite able to produce the electric light.

*Wilde's Machine*, Fig. 1127, is similar in principle to the foregoing. The external current from a small Siemens machine, *M*, is made to pass through a large coil *A B*, inclosing a soft-iron horseshoe

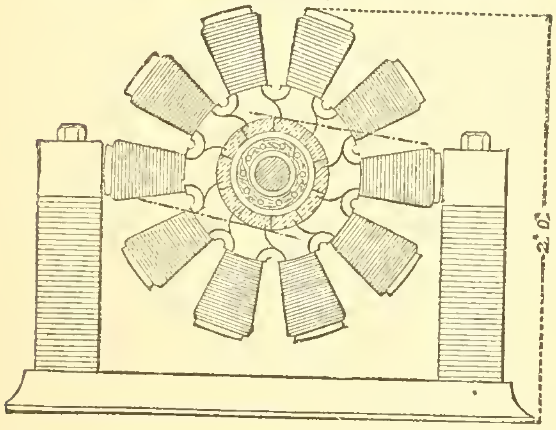
1126.




1127.

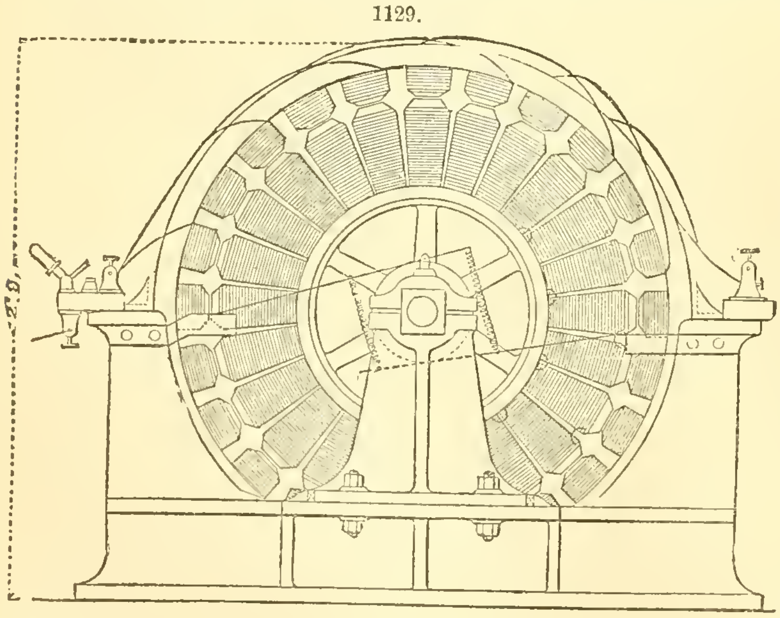



1128.



bar, which is thereby magnetized, and acts as a permanent magnet on a second revolving core *F*, larger than but similar to that of the smaller apparatus. The latter core collects a much more powerful current than that first produced, and this can be used to generate a third or higher order of current; but with each such increase of current the power required to turn the cores is increased. A machine of this class has been constructed capable of melting rods of iron 15 inches long and a quarter of an inch thick, the total weight of the apparatus being 4½ tons.

1129.

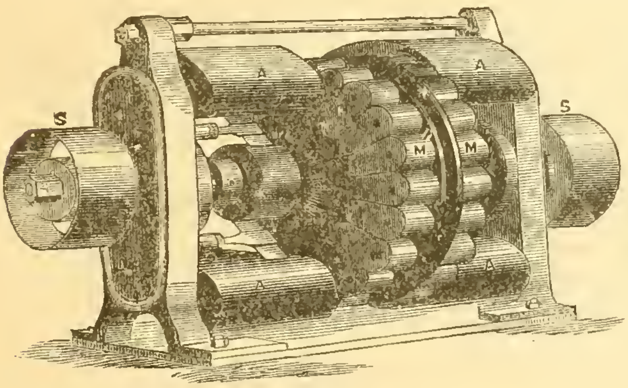


*The Lontin Machine* is designed for producing the electric light, and is adapted in a special form for securing its divisibility. The generating machine, Fig. 1128, consists of a horseshoe electro-magnet, having its two arms placed vertically upward. Between these arms rotates an induction coil, in form like a pinion; the cylindrical teeth, round which the coils are made, are fixed radially into a core or revolving axle of soft iron. A number of these pinions, proportionate to the required strength of the machine, are added side by side on the core, each pinion forming a complete circuit of itself. In the arrangement of these pinions upon the core common to all, the corresponding teeth of the several pinions are not ranged in a horizontal line lengthwise along the revolving shaft, but in a spiral. By this means any interruption of interval between the passage before the poles of the electro-magnet of one set of teeth of the induction coil and that of the succeeding set is avoided. Two friction-rods collect, one the positive, the other the negative currents, which are passed off through the coils of the electro-magnet, thereby

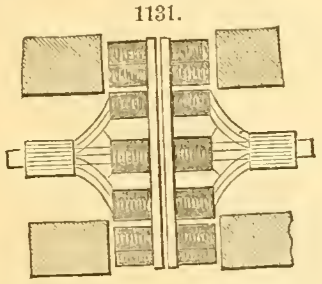
intensifying its action, and so in one continuous direction to the second machine. This second or "dividing" machine, Fig. 1129, consists of a revolving drum carrying (fixed exteriorly like the spokes of a wheel) a series of electro-magnets, into the coils of which the currents from the "generating" machine, Fig. 1128, are passed, and which are always kept thereby in magnetic saturation. This magnetic wheel revolves within a fixed wrought-iron cylinder, having on its inside a number of induction coils corresponding to that of the radial spokes in the revolving wheel. The coils of these spokes are all coupled together, but in such a manner that while one spoke-magnet has its positive pole at the outside extremity next to the induction coils, the succeeding spoke will present at the outside end its negative one; and so on are the spokes made to alternate in their poles round the circumference of the revolving wheel. The result is that the latter during its passage induces a number of currents alternate in direction, and equal in number to half that of the spokes. Each of these currents is collected directly and separately upon the fixed exterior drum, and conveyed to a manipulating frame outside, where by suitable arrangements the various elementary currents may be coupled and combined together in one or in any desired number of circuits. The apparatus in the diagram, having 24 spokes, can, by coupling them in pairs, produce 12 circuits, or any less number which may be desired; and furthermore, the entire current of each circuit may be devoted to a single lamp, or to the production of a series of as many lights as it can support.

The double Lontin machine shown in the diagrams is capable of supplying a total illuminating power of 12,000 standard candles, if the generating machine is driven at 220 revolutions per minute, and the distributing at about 360; but a much larger illuminating power may be obtained if driven at a proportionately higher speed. The usual motor is an engine of 8 horse-power nominal. The number of lights generally produced varies from 6 to 12, the luminous intensity of each diminishing as the number is increased; but as many as 30 have been supplied from it for a length of time at one of the railway stations in Paris, where a higher rate of production than above given was required.

1130.




1131.



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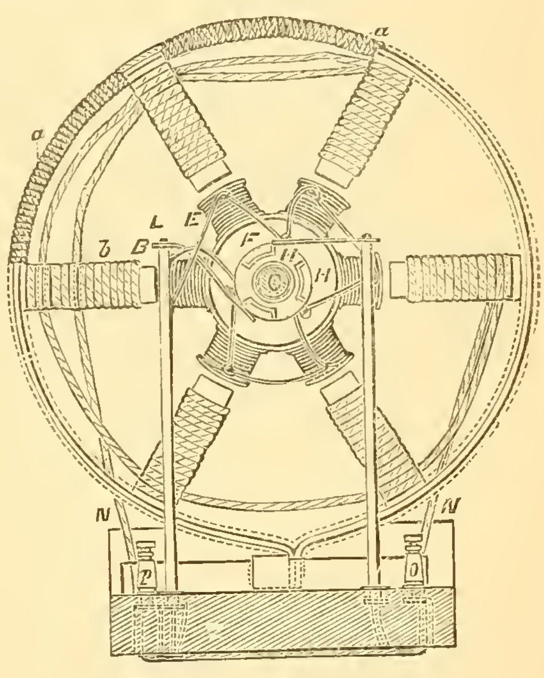


*The Wallace-Farmer Machine* consists of 2 horseshoe magnets, *A A*, Fig. 1130, with the poles of opposite character facing each other. These give the magnetic field. The shaft *S S* passes between the arms of the magnets, and is rotated by pulleys from both ends. The revolving electro-magnets *M M* are carried on the shaft, so as to face the field magnets. Each horseshoe magnet has its own set of revolving coils, the latter being separated by an air space between the armatures. In each set of coils there are 25 magnets, and, as the average rotation of the shaft is about 800 turns per minute, each magnet cuts a field of force 1,600 times per minute. Instead of being wound in the ordinary way, the coils have 4 wires. It will be seen that this constitutes a double machine, each series of coils, with its commutator, being capable of use quite independently of the other; but in practice the electrical connections are so made that the currents generated in the two series of armature coils pass through the field-magnet coils, and are joined in one external circuit. The machine, it is stated, may be used without a commutator to produce an alternating current. Fig. 1131 exhibits a section of the apparatus, showing the brushes.

*The Weston Machine*, Fig. 1132.—When the apparatus is first made, the stationary electro-magnets *B* are for a moment put in connection with a battery or some other source of electricity, and after this they will always retain a small amount of residual magnetism. The belt from the engine, for example, being put upon the driving-pulley, the armatures are put in rapid revolution, and a weak current of electricity is produced, which, flowing through first one half of the commutator, and then through the other half, as the case may be, is passed through suitably-arranged connecting-wires *N N'* to the coils *b b*, which surround the magnets *B B B B*, and, if desired, through the coils *a a* surrounding the iron ring *A*. This current, small at first, excites the magnets *B B B B*, producing the maximum effect. The current, after passing through the coils *b b b b* and *a a a a*, flows through any

desired circuit, the wire being led from the screw-cap *o*. Then, to complete the circuit, it returns to the machine at the screw-cap *p*, up through the spring or brush *L*, into first one half of the commutator, and then into the other, as the case may be, completing in this way the circuit from the coils surrounding the revolving armatures *E E E E*, then back again to these coils, having, during its passage, been utilized for any purpose to which electricity is or may be applied, and in its passage exciting the stationary electro-magnets *B B B B*. One half of the number of coils which compose the armature are connected with, for example, the part *H* of the commutator, and the remainder with the part *H'* of the commutator, for half of the separately-wrapped armatures are positive and the other half negative, alternately. It is claimed that the entire current generated in or by all the coils of the revolving armature is passed through the coils surrounding the magnets *B B B B*, and the coil surrounding the ring or cylinder *A*, and that none of the armatures are set apart specially for the purpose of generating a current whose sole duty it shall be to excite the magnets *B B B B*. This machine has proved itself well adapted for electro-metallurgical uses.

*The Gramme Machine.*—This apparatus, from the remarkable ingenuity exhibited in its construction and its notable economy and efficiency, has achieved a success which has led many to regard it

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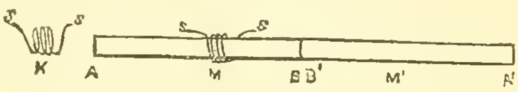
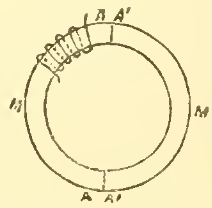


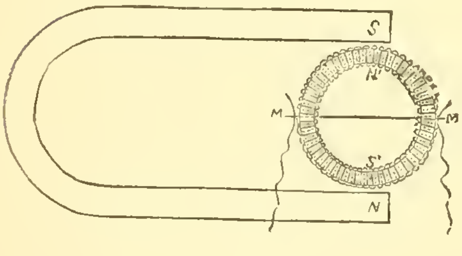

1134.




as the most advantageous form of magneto-electric machines yet (1879) devised. For an extended discussion of the principles involved in it the reader is referred to a paper on the subject by M. Gaugain published in the *Annales de Chimie et Physique*, 1873, and also to M. Hippolyte Fontaine's work on electric illumination (London, 1878; Paris, 1877). The essential points may be briefly stated as follows: When a bar magnet is introduced into a coil of insulated wire, a temporary current of electricity is set up in the wire, lasting only over the period during which the bar is being introduced. On withdrawing the bar, a secondary current is caused in the wire, which flows in opposite direction to the former current. If the magnet, instead of being inserted and then withdrawn, be carried entirely through the coil, it obviously in its passage comes opposite a succession of spirals or turns of wire. As it does so, it produces in each spiral a current, and these currents will all be in the same direction until the middle point or neutral axis of the magnet is reached. After that a current in reverse direction is caused. Hence, during the passage of the magnet there is produced, first a direct, and then a reversed current.

If, instead of one bar magnet, two are placed end to end so that the two poles of the same name are in contact, and the coil passed over both, the phenomenon last noted will take place in the coil for each magnet separately. If in Fig. 1133 the coil be made to move over these bars, we shall

1135.

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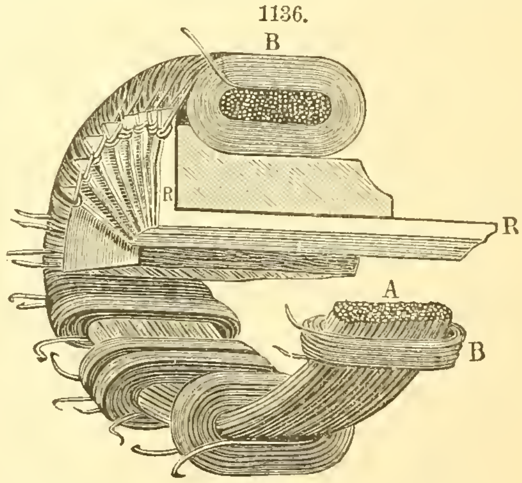


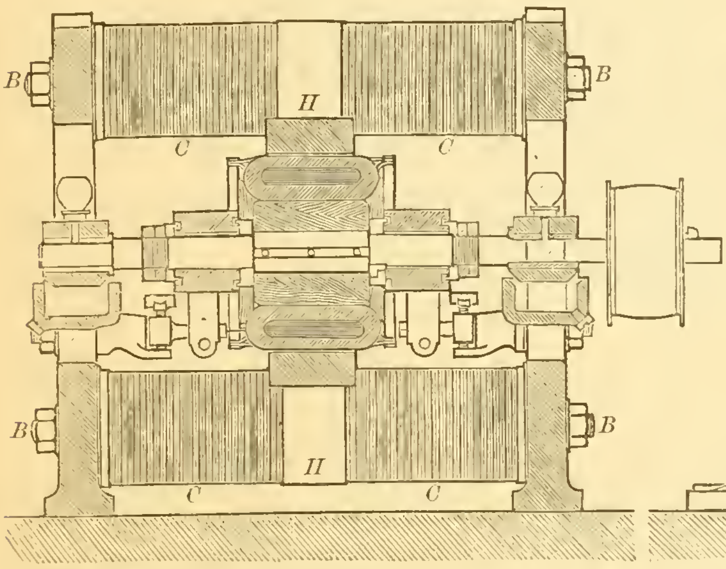

find that in the first quarter of the stroke, as we may term it, from *A* to *M*, we shall have a positive current; in the second quarter, from *M* to *B*, a negative current; again, a negative current from *B'* to *M'*; and finally, a positive current from *M'* to *A'*. It must also be evident that the same results will be caused if, instead of passing the coil over the magnets, the latter were made in circular form, as shown in Fig. 1134, and caused to pass through the coil. In order, however, to avoid the mechanical complications incident to apparatus for accomplishing this, M. Gramme devised the apparatus outlined in Fig. 1135. This is a permanent horseshoe magnet, between the poles of which, *N S*, is placed a ring of soft iron, around which is wound a coil of insulated wire. This ring is not a permanent magnet, but when placed in the position shown becomes so by induction from the permanent magnet. The two poles *S' N'* will then be established in the ring. If the ring be caused to revolve, the poles will remain unaltered in space—that is to say, they will remain at *N' S'*; and it follows that every portion of the ring will alternately become a north and a south pole. The consequence is, that the poles may be regarded as constantly traveling through the iron ring at the same

rate as that at which it revolves, but in an opposite direction; and the effect on the wire coiled on the ring is then precisely the same as though the magnet in Fig. 1135 revolved within the wire which was held at rest. It is on this translation of polarity that the Gramme machine depends for its action; and to go back to our starting-point, its difference from other machines may be summed up in the fact that, while in the latter the magnet may be regarded as alternately entering and being withdrawn from the coil, in the Gramme machine the magnet is to all intents constantly passing entirely through the coil. In order to collect the electricity produced, the insulating material is removed from the wire in a narrow band round the outside of the ring, and two rubbing collectors take it up in the ordinary way.

The construction of the ring is shown in Fig. 1136. It is composed of a group of soft-iron wires *A*, over which the enveloping wire *B* is put on in separate insulated coils. The radius pieces *R* are insulated from each other by ribbons of silk or India-rubber. The end of the wire terminating one coil and the beginning of the wire of the next succeeding coil are each attached to one radius piece by loops and notches in the way shown. The tails of the radius bars are all grouped together round the central axis, and they are rubbed against by suitable collectors which take up the electricity.

The standard machine used for illuminating workshops and factories is represented in Figs. 1137 and 1138, and consists of two vertical frames of cast-iron, united by four bars of soft iron, *B B B B*,

1137.

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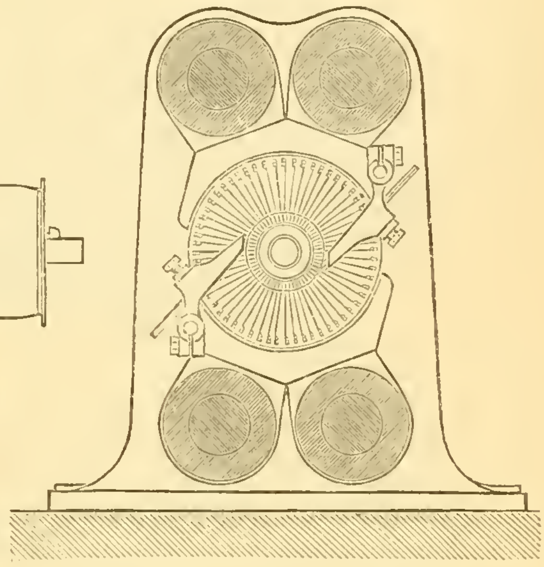


which serve as cores for the electro-magnets *C C C C*. The axis is of steel, and revolves on long bearings, which can be effectively lubricated—a point of importance, as the speed is high, ranging from 700 to 1,350 revolutions per minute. The central ring, instead of being covered with a single wire attached by equal portions to a common collector, is covered with two wires, wound on side by side and united with two collectors. The poles of the electro-magnets *H H* are much developed, embracing seven-eighths of the circumference of the ring. Four wipers (*balais*) *J J* pick up the electricity. The electro-magnets are placed in the current, and the machine, like Ladd's, depends for the power of starting upon the small residual magnetism which remains permanently in them.

The following are the leading dimensions of a machine of this class, varying of course with the nature of the work and the power required. In the form of machine most usually employed for military purposes, flat electro-magnets are used; for ships there are four horizontal columns; for signals the machine is very small, and may be worked by manual labor, etc. For industrial purposes there is but one type of machine, of the following dimensions:

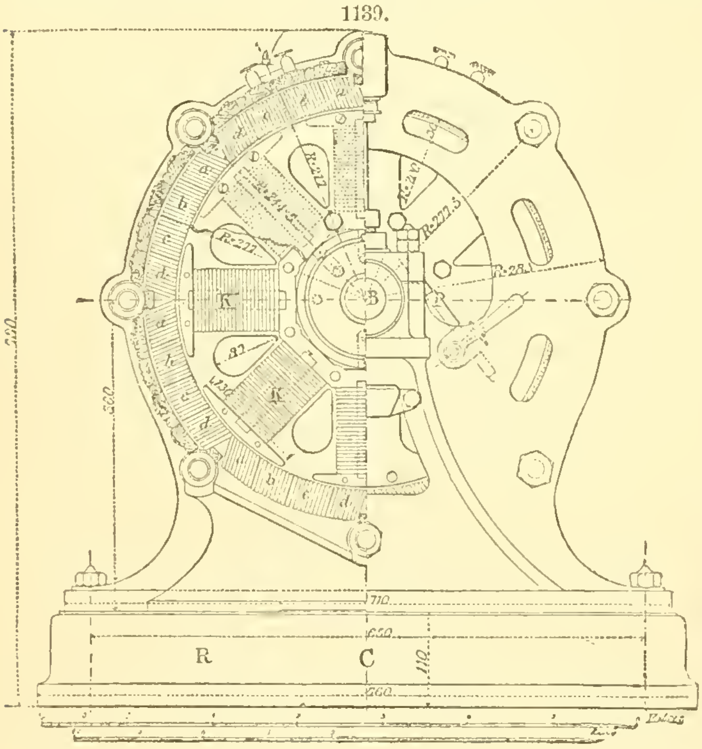
| | |
|---|---|
| Total length | 21.6 inches. |
| " width | 14.75 " |
| " height | 21.6 " |
| Volume | 4 cubic feet. |
| Diameter of the bobbin | 7 inches. |
| Number of revolutions per minute | 850 turns. |
| Weight of the copper in action | 70 lbs. |
| Total weight | 397 " |
| Power necessary for driving the machine | $2\frac{1}{2}$ horse-power. |

With regard to the estimation of the illuminating power, it is to be remarked that if the regulator and the photometer be placed in the same horizontal line, and the axes of the two carbons in the same vertical line, a light equal to 2,400 candles is produced. If the regulator be suspended at a height of 16.4 feet, and the measure be taken below at 16.4 feet from the foot of the regulator, the upper carbon acts as a reflector, and 8,400 candles are indicated by the photometer. Again, if the measure be taken as in the first case—the photometer and the regulator at the same level—while the lower carbon is fixed a little in advance of the upper carbon, so as to create a dazzling screen behind it, then 6,400 candles are obtained. The power, $2\frac{1}{2}$ horse-power, is constant in the three cases. (See *Engineering*, xxv., 526.)

*The Alternating-Current Gramme Machine.*—The machine above described produces a current in

only one direction, similar in fact to that from a voltaic battery. In such a current the positive carbon of an electric lamp is consumed at twice the speed of the negative. To obviate this, alternating currents may be used, when each carbon will be burned at an equal rate, each being alternately positive and negative to the other. M. Gramme has so arranged his machine as to produce an alternating current, and by further modifications he causes that current to be divided so as to supply electricity to 4, 6, 16, or more lamps or Jablochkoff candles. This machine is used (1879) in supplying the street lights of Paris, and is represented in Fig. 1139. It consists of a ring of soft iron similar to that already described. This is wound with coils of insulated copper wire, but the direction of winding is alternately right- and left-handed, the wire being wound in one direction so as to cover one eighth part of the circumference of the ring, then changing its direction, being wound in the contrary way over the next eighth part, and so on round the ring, each of the eight sections of the ring being wound in the reverse direction to that in which its two contiguous sections are wound. Thus, while the earlier Gramme ring might be described as an electro-magnet bent round in a circle and joined to itself, the ring of the new machine may be looked upon as 8 curved electro-magnets placed end to end with their similar poles in contact, so as to form a circle. This ring is rigidly fixed in a vertical position to the solid framing of the apparatus, the inducing electro-magnets revolving within it. Here again it differs from the continuous-current machine, in which the magnets are fixed, and the ring is rapidly rotated in the magnets fixed between their poles. The electro-magnets, of which there are 8, are fixed radially to a central boss revolving upon a horizontal steel shaft running in suitable bearings attached to the framing, and an external pulley enables the machine to be driven by a band from a steam-engine or other motor. The radial electro-magnets are alternately right- and left-handed in the direction in which their coils are wound, so that if they be numbered respectively 1, 2, 3, 4, etc., up to 8, those represented by even numbers will have one polarity when a current is sent through them all together, while those whose numbers are uneven will have an opposite polarity. The poles farthest from the central boss in all the magnets are spread out so as to increase the area of the magnetic field by which electric currents are

1139.



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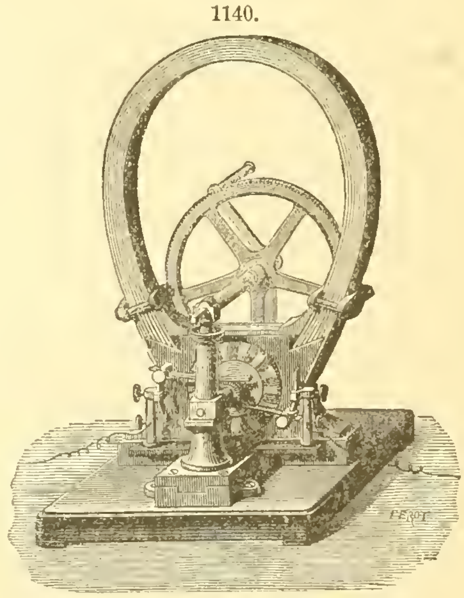


induced in the coils of the ring. Each of the 8 sections of the induction ring is made up of four subsections, *a b c d*, *a b c d*, etc., all of which in any one section are wound in the same direction. By coupling the coils of these sub-sections in various ways, a division of the current may be made into 32, 16, 8, or only 4 circuits. In order to obtain 4 currents from the machine by which 4 lamps may be illuminated, all that is necessary is to connect together in series all the coils marked *a* for one circuit, all the coils marked *b* for a second circuit, all the coils marked *c* for a third circuit, and all the coils marked *d* for a fourth circuit.

*Table showing Capacity of the Gramme Alternating-Current Machine.*

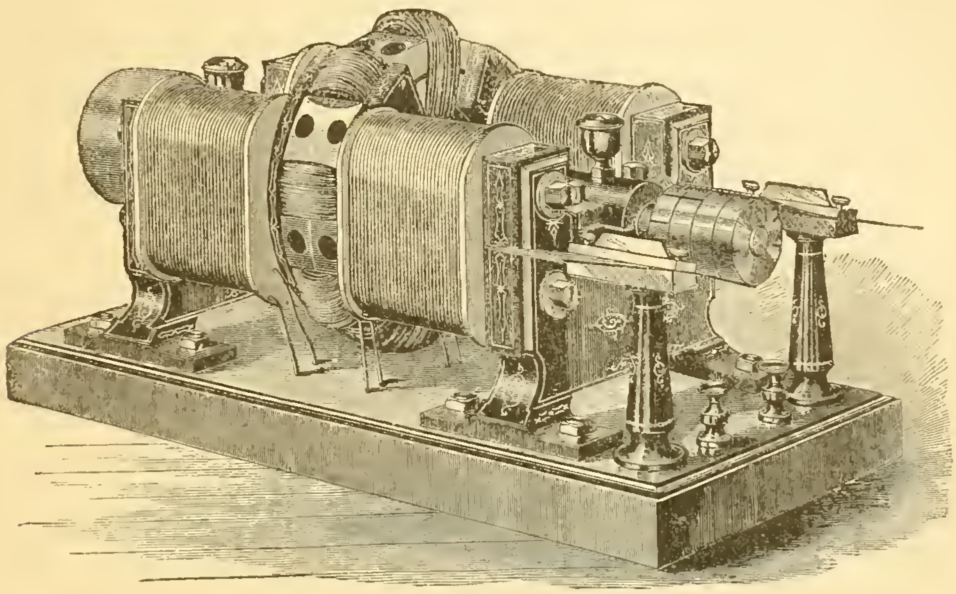
| NUMBER. | Length, inches. | Width, inches. | Height, inches. | Weight, lbs. | Number of Jablochkoff Candles supplied. | Speed, Revolutions per Minute. | Horse-power consumed. |
|---|---|---|---|---|---|---|---|
| I. | 35 | 30 | 30 | 1,250 | 16 | 600 | 16 |
| II. | 27 | 15 | 20 | 500 | 6 | 700 | 6 |
| III. | 21 | 15 | 18 | 350 | 4 | 800 | 4 |

*The Permanent Magnet Gramme Machine* is represented in Fig. 1140. The magnet is of the type devised by M. Jamin (see MAGNET), and the apparatus is competent to give a current equivalent to that produced by 8 Bunsen elements, so that it is well adapted for experimental purposes.

M. Fontaine's work previously quoted contains very full data as to the comparative cost of the Gramme machine for purposes of electric illumination. See also *Engineering*, xxvi., 65.

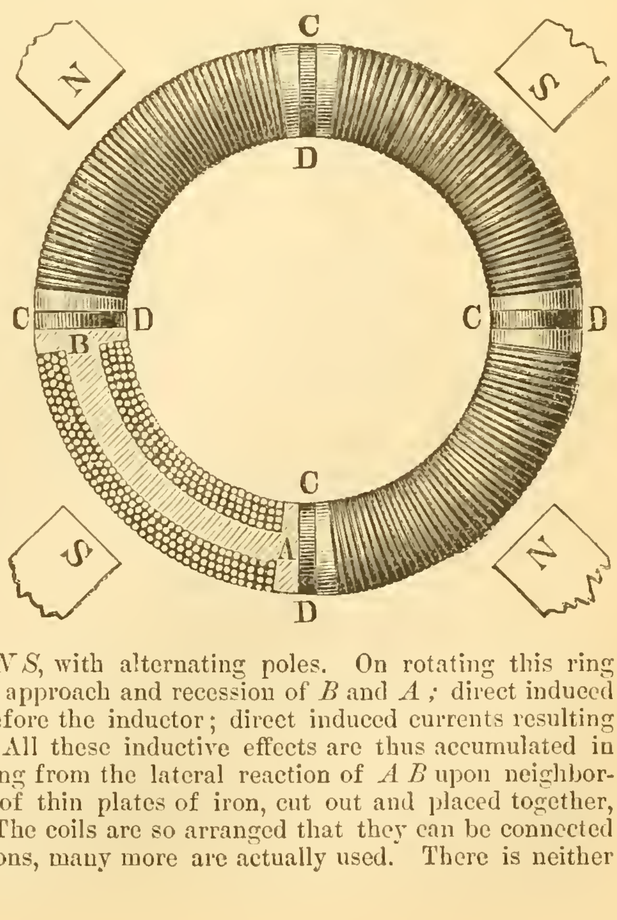
*The Brush Machine*, Fig. 1141.—There are two marked differences between this and other machines, the first of which consists in the peculiar method adopted for winding the armature. The latter is composed of a ring or endless band of iron, but, instead of having a uniform cross-section, like that of the Gramme machines, is provided with grooves or depressions whose direction is at right angles to its magnetic axis or length. These grooves, which may be of any suitable number, according to the uses for which the machine is designed, are wound full of insulated copper wire.

1141.



The advantage of winding the wire in grooves or depressions in the armature is twofold. First, the projecting portions of the armature between the sections of wire may be made to revolve very close to the poles of the magnets from which the magnetic force is derived. By this means the inductive force of the magnets is utilized to a much greater extent than is possible in the case of annular armatures as ordinarily used, which are entirely covered with wire, and cannot therefore be brought very near the magnets. Second, owing to the exposure of a very considerable portion of the armature to the atmosphere, the heat, which is always developed by the rapidly succeeding magnetizations and demagnetizations of armatures in motion, is rapidly dissipated by radiation and convection. In the case of armatures entirely covered with wire, the escape of the heat is very slow, so that they must run at a comparatively low rate of speed, with corresponding effect, in order to prevent injurious heating. The second difference lies in the manner of connecting the armature coils to the commutator, this being such that only the particular coils which contribute to the production of the current are in circuit at once. During the time they are passing through the neutral points in the magnetic field, they are cut out one after the other, and thus, while idle, do not tend to weaken the effects of the machine by affording a path to divert the current generated in the active sections from its proper channel.

1142.




*The De Méritens Machine*, Fig. 1142, consists of a Gramme ring divided into four sections insulated magnetically the one from the other, and forming consequently four electro-magnets placed end to end. The iron core of each of these sections is terminated at each end by a piece of iron $A\,B$, forming expanded prolongations of the poles. All these parts are joined by pieces of copper $C\,D$, to form one solid ring, around which are placed permanent magnets $N\,S$, with alternating poles. On rotating this ring reverse induced currents are caused through the approach and recession of $B$ and $A$; direct induced currents during the passage of the core $A\,B$ before the inductor; direct induced currents resulting from the passage of the helix in front of $N$. All these inductive effects are thus accumulated in this combination; there are also currents resulting from the lateral reaction of $A\,B$ upon neighboring poles. The core and appendages are made of thin plates of iron, cut out and placed together, to the number of 50, each 1 millimetre thick. The coils are so arranged that they can be connected in series or for quantity. Instead of four sections, many more are actually used. There is neither

commutator nor collector, and consequently no loss of current. This machine has supplied regulators even when the carbons were separated by a distance of 1.3 inch.

*Results of Experiments on Dynamo-Electric Machines.*—In May, 1878, a committee of the Franklin Institute instituted competitive tests between the Gramme continuous-current machine, two sizes of the Brush, and two sizes of the Wallace-Farmer. The principal results are given below:

*Table showing Weight, Power absorbed, Light produced, &c., by Dynamo-Electric Machines tested by a Committee of the Franklin Institute,* 1877–'78.

| NAME OF MACHINE. | Weight in Pounds. | COPPER WIRE IN: ARMATURE. Size. | ARMATURE. Weight | FIELD MAGNETS. Size. | FIELD MAGNETS. Weight | Revolutions of Armature per Minute. | Foot-pounds of Power consumed. | Horse-power. | LIGHT PRODUCED IN STANDARD CANDLES. Total. | Per h. p. | Foot-pounds of Power consumed per Candle-light. | Size of Carbons. | LENGTH OF CARBON CONSUMED PER HOUR. + | − |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Inch. | Lbs. | Inch. | Lbs. | | | | | | | | | |
| Large Brush... | 475 | .081 | 32 | .134 | 100 | 1,340 | 107.606 | 3.26 | 1,230 | 377 | 87.4 | ⅜ × ⅜ | 1.78 | .34 |
| Small Brush... | 390 | .063 | 24 | .096 | 80 | 1,400 | 124.248 | 3.76 | 900 | 239 | 137. | ⅜ × ⅜ | 1.91 | .58 |
| Large Wallace. | 600 | .042 | 50 | .114 | 125 | 800 | | | 823 | | | | | |
| Small Wallace. | 350 | .043 | 18¾ | .098 | 41 | 1,000 | 128.544 | 3.89 | 440 | 113 | 292. | ¼ × ¼ | 2.45 | .073 |
| Gramme..... | 366 | .059 | 9½ | .108 | 57½ | 800 | 60.992 | 1.84 | 705 | 383 | 85. | ¼ × ¼ | 3.15 | .55 |

As regards efficiency, Professors E. H. Houston and Elihu Thomson state that:

1. The Gramme machine is the most economical, considered as a means for converting motive power into electrical current, giving in the arc a useful result equal to 38 per cent., or 41 per cent. after deducting friction and the resistance of the air.

2. The large Brush machine comes next in order of efficiency, giving in the arc a useful effect equal to 31 per cent. of the total power used, or 37½ per cent. after deducting friction. This machine gave the most powerful current, and consequently the greatest light.

3. The small Brush machine stands third in efficiency, giving in the arc a useful result equal to 27 per cent., or 31 per cent. after deducting friction.

4. The Wallace-Farmer machine does not return to the effective circuit as large a proportion of power as the other machines, although it uses, in electrical work, a large amount of power in a small space. The cause of its small economy is the expenditure of a large proportion of the power in the production of local action. (See *Journal of Franklin Institute*, May and June, 1878.)

In 1876–'77 Professor Tyndall conducted trials on several dynamo-electric machines at the South Foreland lighthouse, England, with the following results:

*Table showing Dimensions, Weight, Horse-Power absorbed, and Light produced by Dynamo-Electric Machines at South Foreland,* 1876–'77.

| NAMES OF MACHINES. | DIMENSIONS. Length. | Breadth. | Height. | Weights. | Horse-power absorbed. | Revolutions per Minute. | Light produced in Standard Candles. Condensed Beam. | Diffused Beam. | Light produced per Horse-power in Standard Candles. Condensed Beam. | Diffused Beam. | Size of Carbons. | Order of Merit. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | ft. in. | ft. in. | ft. in. | lbs. | | | | | | | in. in. | |
| Holmes............ | 4 11 | 4 4 | 5 2 | 5,132 | 3.2 | 400 | 1,523 | 1,523 | 476 | 476 | ⅜ by ⅜ | VI. |
| Alliance............ | 4 4 | 4 6 | 4 10 | 3,646 | 3.6 | 400 | 1,953 | 1,953 | 543 | 543 | ⅜ " ⅜ | V. |
| Gramme (No. 1).... | 2 7 | 2 7 | 4 1 | 2,550 | 5.3 | 420 | 6,663 | 4,016 | 1,257 | 758 | ½ " ½ | IV. |
| Gramme (No. 2).... | 2 7 | 2 7 | 4 1 | 2,550 | 5.74 | 420 | 6,663 | 4,016 | 1,257 | 758 | ½ " ½ | IV. |
| Siemens (large)..... | 3 9 | 2 5 | 1 2 | 1,168 | 9.8 | 480 | 14,818 | 8,932 | 1,512 | 911 | 11/16 " 11/16 | III. |
| Siemens (small, No. 58)...... | 2 2 | 2 5 | 0 10 | 375 | 3.5 | 850 | 5,539 | 3,339 | 1,582 | 954 | ½ " ½ | II. |
| Siemens (small, No. 68)...... | 2 2 | 2 5 | 0 10 | 375 | 3.3 | 850 | 6,864 | 4,138 | 2,080 | 1,254 | ½ " ½ | I. |
| 2 Holmes.......... | 9 10 | 4 4 | 5 2 | 10,264 | 6.5 | 400 | 2,811 | 2,811 | 432 | 432 | ½ " ½ | ... |
| 2 Gramme......... | 5 2 | 2 7 | 4 1 | 5,100 | 10.5 | 420 | 11,396 | 6,869 | 1,085 | 654 | 11/16 " 11/16 | ... |
| 2 Siemens (small, Nos. 58 and 68) | 4 4 | 2 5 | 0 10 | 750 | 6.6 | 850 | 14,134 | 8,520 | 2,141 | 1,291 | 11/16 " 11/16 | ... |

In "Proceedings of the Royal Society," 1878, Captain Abney, F. R. S., publishes the results of experiments on the Gramme machine, in which he shows that the electromotive force increases directly as the number of revolutions of the armature, and that the current for any given number of revolutions varies inversely as the resistance in circuit; or, in other words, that the electromotive force for a given number of revolutions is constant. The dynamics of electric lighting by the use of the dynamo-electric machine is discussed by Mr. Robert Briggs in *Engineering*, xxvi., 316, and by Mr. Silvanus P. Thompson in the same journal, xxvi., 341. The former writer points out that the Franklin Institute experiments above detailed gave as a result but 380 candles of light as proceeding from 1 horse-power. Starting from this, he analyzes the theoretic expenditures of heat (or force) in producing both gas and electric lights, and comes to the conclusion that the relative expenditures

of heat and fuel practically of the electric system by the dynamo-electric machines and steam-engine, as compared to that of coal-gas for equal quantities of light, is at present 1 to 2.2; while in the processes there will have been burned as fuel 1 lb. of coal under a steam-boiler, against $5\frac{1}{4}$ lbs. of coal treated in the retort for the manufacture of coal-gas.

No subject is more prominently before inventors (1879) than the adaptation of the dynamo-electric machine to the economical production of the divided electric light; and the reader is therefore specially referred to the files of *Engineering*, *Scientific American*, *Journal of the Franklin Institute*, and other periodicals of later date than this work, for possibly important advances and discoveries.

DYNAMOMETER. A dynamometer, strictly speaking, is a device to measure force overcoming resistance or producing motion. Ordinary scales and spring-balances become dynamometers when used to measure the intensities of applied forces, instead of dead weights. But the name is usually employed to designate apparatus for special purposes, embodying in its construction devices for indicating or recording the distance the forces move through, as well as the intensities of the successive forces exerted. If the force be measured in pounds, and the distance the force moves through in feet, the work done in foot-pounds equals the product of the force by the distance. The unit of power is one horse-power, equivalent to 33,000 foot-pounds per minute (or 550 foot-pounds per second, 1,980,000 per hour, etc.); so the number of horse-powers developed in any given case equals the number of foot-pounds of work performed per minute divided by 33,000. For instance, if a horse pull a load through a spring-balance showing an average tension of 150 lbs., the work done in moving the load 220 feet would be $150 \times 220 = 33,000$ foot-pounds; and if it were done in one minute, there would have been developed what is conventionally termed one horse-power. To obtain the power requires then three classes of apparatus: 1, the dynamometer proper, to measure the forces exerted; 2, devices to measure and indicate or register the distance the forces act through—such devices often forming part of the dynamometric apparatus; and 3, devices for ascertaining the time in which the work is performed. Frequently the inspection of a timepiece in connection with the readings of the instrument is considered sufficient for the purpose last named, though occasionally elaborate velocimeters are embodied in the construction of the dynamometer.

Dynamometers may be divided into three classes, viz.: *traction*, *thrust*, and *rotary*. Traction dynamometers are employed chiefly to ascertain the absolute and relative resistance of vehicles of different kinds, when varied in the details of construction, or used under various conditions as to the road, the grade, the loads imposed, the size of wheels, the lubrication, etc.

SPRING-BALANCES.—*An ordinary Spring-Balance* is a simple spiral spring, to be extended by the application of a load, the degree of extension being marked by an index on a scale attached to the case of the instrument. In the larger instruments one or more smaller springs are put inside a larger one. When it is desired to indicate the smaller fractional parts of a pound with instruments of

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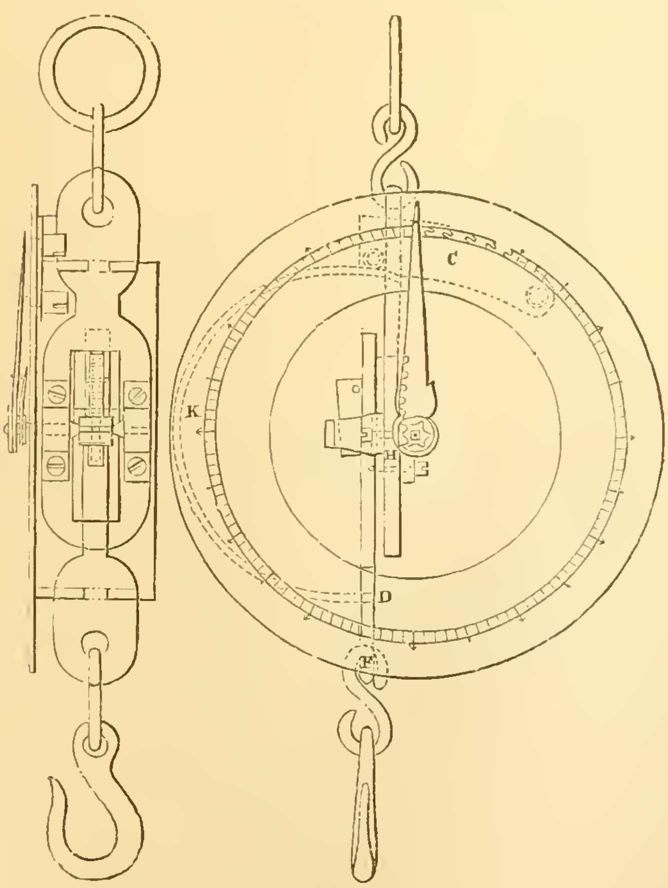

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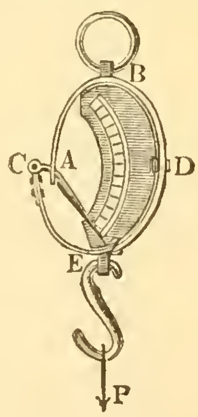


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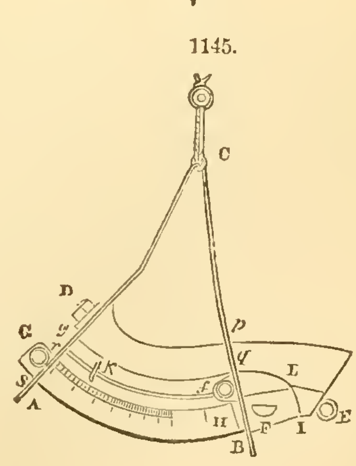

considerable capacity, the movement of the free end of the spring is applied through a rack and pinion to move an index on a dial, thereby obtaining a wider range for the smaller divisions, the larger ones being marked on the slide.

*A curved Spring-Balance*, of a French type, is shown in Fig. 1143. The spring is flat and bent to

the shape $C\,K\,D$. The upper branch passes through a draw-plate which carries the case of the instrument. The lower branch is attached to the lower draw-plate, which has at its lower end a hook to receive the load, and is connected above to a rack engaging with a central pinion on an axis carrying an external index-finger, operating in connection with a dial engraved on the case, as shown.

*An open Steel-Ring Balance* is shown in Fig. 1144. A dial is secured to the rear of the spring $D$, and the index is traversed over it by connection of the two free ends $A$ and $C$ of the spring respectively with the fulcrum and end of the index-lever.

*Spring-Balance and Eprouvette.*—The spring-balance illustrated in Fig. 1145 is formed of two steel branches $A\,C$, $C\,B$, bent at an angle of 45° ; each of the arcs $D\,p\,q\,E$, $I\,H\,G$, is fixed to one of the branches and traverses the other. By drawing the rings $E\,G$, which terminate the arcs, in opposite directions, we bring the branch $A\;C$ near $B\;C$; a circular scale figured from 5 to 40 indicates the respective positions of these two branches. The branch $A\;C$ pushes before it a small cursor $k$ of card or leather, which slides easily on the metallic wire $f\,g$, attached to the branch $C\,B$ of the balance. To graduate the scale, suspend the balance by a ring $E$ fixed to the branch $A\;C$, and attach weights to the ring $G$, which is at the extremity of the scale. The numbers on the scale indicate the tension of the spring. Regnier has made an excellent instrument of this spring-balance for trying the strength of powder. The length of the branches $A\;C$ and $C\,B$ is about 4.8 inches, and their

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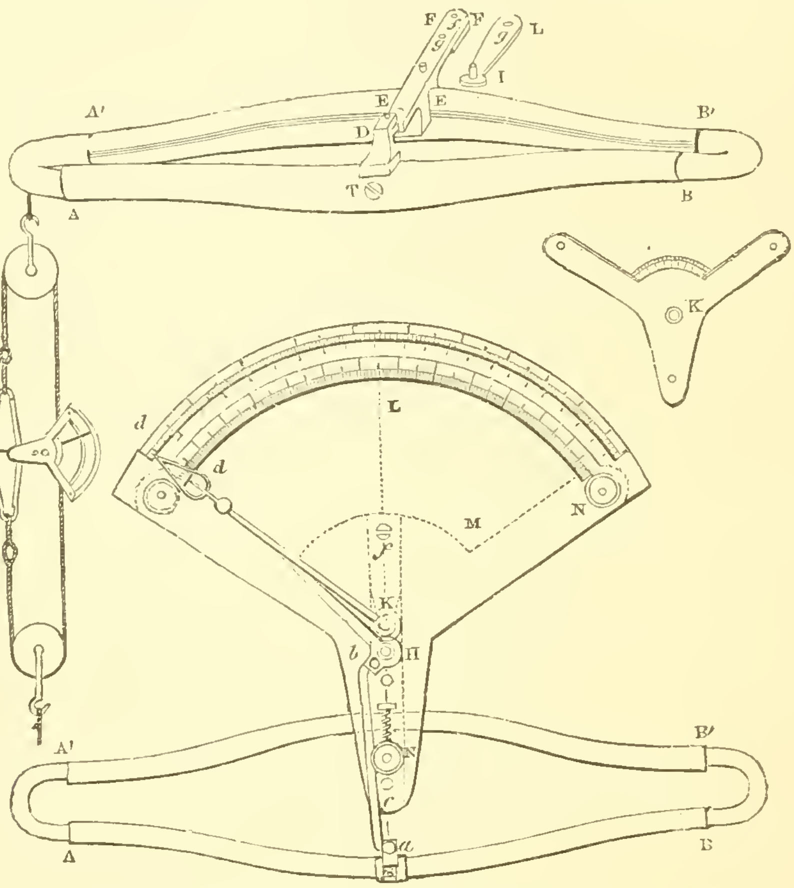


breadth about an inch ; a small brass cannon, whose breech $H$ is on the branch $C\,B$ of the balance, and whose mouth $I$ is closed by the fuse $I\,L$ of the obturation $D\,I\,L\,E$ fixed on the other branch $A\;C$ of the balance, contains a given weight of the powder to be tried ; it is primed by a little powder put in the pan $F$; the powder within the cannon is fired and drives it away ; after the ignition the two branches of the balance approach, and the cursor $k$ indicates on the scale the tension of the spring at the moment of the explosion. The iron $D\,E$, and the brass arc $G\,H$, on which the scale is drawn, pass through openings $p\,q$, $r\,s$, made in the middle of the plates $C\,B$ and $C\,A$.

*Regnier's Dynamometer*, represented in Fig. 1146, resembles a common graphometer, the principal part of which instrument is a steel spring bent in the form of an ellipse; it should be properly tempered and well welded, and covered with leather, to prevent injury to the hands when used. This spring is represented by $A\,A'$, $B\,B'$, formed by two equal plates united at the ends by rounded half-rings. The dimensions of this spring vary according to the tension required, or the weight to which it is applied. The dynamometer used to ascertain human strength weighs little more than 2 lbs., and serves to measure a thousand times that weight; its total length is about 12 or 13 inches, its greatest breadth, as measured in the middle of the two arcs, is 2.2 inches, and the least breadth at the extremity of these arcs is three-quarters of an inch. The thickness of the arcs at their centres is nearly 2 inches, and its height, which decreases from the centre toward its ends, from one-tenth to four-tenths of an inch ; the chords of the two arcs are 6.4 inches. This length, added to that of the two demi-rings, gives for the total length of the dynamometer 12 or 13 inches. The distance between the parallel chords is about three-quarters of an inch, and the perpendiculars of the arcs are each seven-tenths of an inch, giving about 2.2 inches for the total distance between the centres of the arcs. There are two methods of stretching the spring, viz., by pressing it in the direction of the perpen-

dicular of the two arcs which form it, and by drawing it with the two rings at right angles to that perpendicular. Separate scales are provided for the two modes of operation, ranging respectively from zero to 264 lbs. avoirdupois, and from zero to one gross ton. They are engraved on a quadrant attached to one limb of the spring, and the double-pointed index *d* is operated by the other limb through a connection *c* and bent lever *b*. The index is provided with a friction-washer at *K*, and retains the maximum position to which it is carried, which is in general undesirable, as a dynamometer should show the average indications. There is, however, another scale on a covering plate (shown detached), on which the averages may be estimated from the end of the bent lever *b*. The capacity of the machine may be doubled by placing it between the two ends of a cord passing over double pulleys, as shown on the left.

In *Morin's Dynamometer*, Fig. 1147, plate springs thickened at the centre and connected together at the ends are used instead of the elliptical spring above illustrated, and apparatus applied to record continuously the magnitude of the forces exerted. The operation will be understood from the description of other apparatus embodying similar details differently arranged.

Dynamometric Registering and Integrating Apparatus.—If a drum carrying a band of paper be put in motion by the vehicle or machine to which the dynamometer is applied, and connections be made so that the straining of the springs will cause a proportional movement of a pencil along the drum parallel with its axis, a diagram will be traced similar to that in Fig. 1159, in which the vertical heights will represent the tensions at the various points, and the undulations show the changes of propelling force or resistance which constantly occur in nearly all machinery, but is particularly noticeable in drawing a common carriage. Registering or recording apparatus of this kind is generally provided with two pencils: one stationary, to mark the zero line of pressure, and a movable one showing the intensities of the efforts. The average force exerted equals the mean height of the diagram, which may be obtained in the manner explained for indicator diagrams. (See Indicator.) M. Morin has however pointed out a simpler method, which is to weigh the paper band on which the diagram is taken and ascertain its surface, then to cut out the diagram and weigh it carefully, when its area in relation to that of the original band may be ascertained by a simple proportion. The distance moved and the time are usually obtained by separate devices, but may be recorded by marks on the band, as in speed indicators.

Integrating apparatus is designed to continually multiply the intensity of the effort by the distance moved through, and thus show a record of the work done. The principle of operation may be understood from Fig. 1148. *A* is an operating disk revolved by connection with the machine or vehicle to be tested. *B* is the integrating disk, which is kept in contact with the disk *A* and is moved across its face from the centre outward by a connection from the dynamometer springs. When the springs are not strained, the integrating disk is at the centre of disk *A*, and receives no motion; but when the load is applied, the disk *B* is moved outward from the centre of *A* a distance proportioned to the

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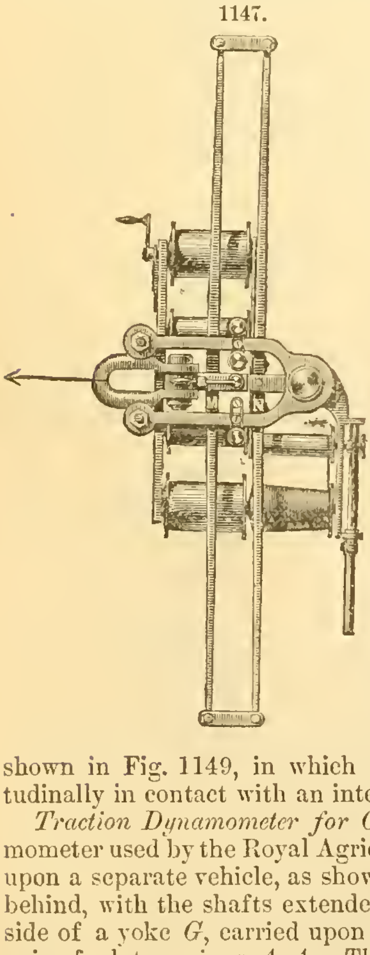

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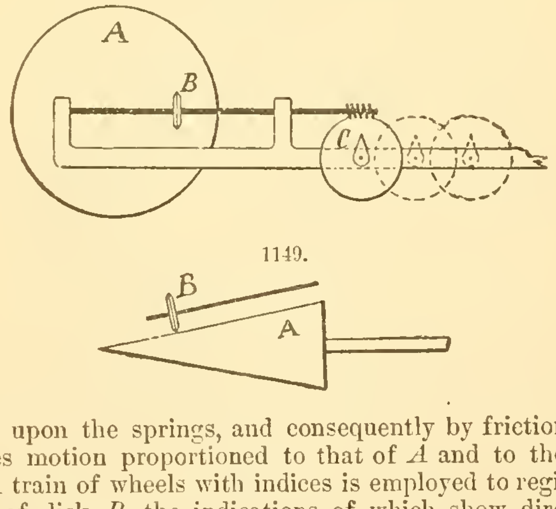


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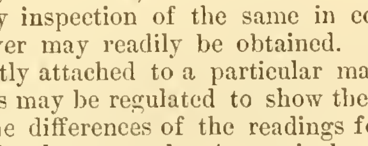


tension put upon the springs, and consequently by frictional contact receives motion proportioned to that of *A* and to the forces exerted. A train of wheels with indices is employed to register the revolutions of disk *B*, the indications of which show directly, or when multiplied by a constant, the number of foot-pounds of work performed; and by inspection of the same in connection with a timepiece, the power may readily be obtained. When the apparatus is permanently attached to a particular machine, the movement of the indices may be regulated to show the horse-power exerted, by taking the differences of the readings for one minute or one hour, as previously arranged. An equivalent arrangement is shown in Fig. 1149, in which a cone *A*, revolved by the machine or vehicle, is also moved longitudinally in contact with an integrating disk *B* by connection with the dynamometer springs.

*Traction Dynamometer for Ordinary Vehicles.*—Figs. 1150 to 1154 inclusive show the horse dynamometer used by the Royal Agricultural Society at Bedford, England. The whole apparatus is mounted upon a separate vehicle, as shown, to which a horse is hitched at one end and the vehicle to be tested behind, with the shafts extended either side of the machine and connected by chains *E F* to either side of a yoke *G*, carried upon casters and pivoted at *E* to the draw-bar *W*, which is connected to a pair of plate springs *A A*. The draw-bar *W* also connects with a piston *D* in a cylinder filled with fluid, the displacement of which from one end to the other can be regulated by a cock in the upper

port shown, and thereby the indicating and registering apparatus be relieved of the sudden movements and continual vibrations incident to rapid variations in force and resistance, without affecting the average results. The movement of the springs is multiplied by a lever *H*, which gives motion

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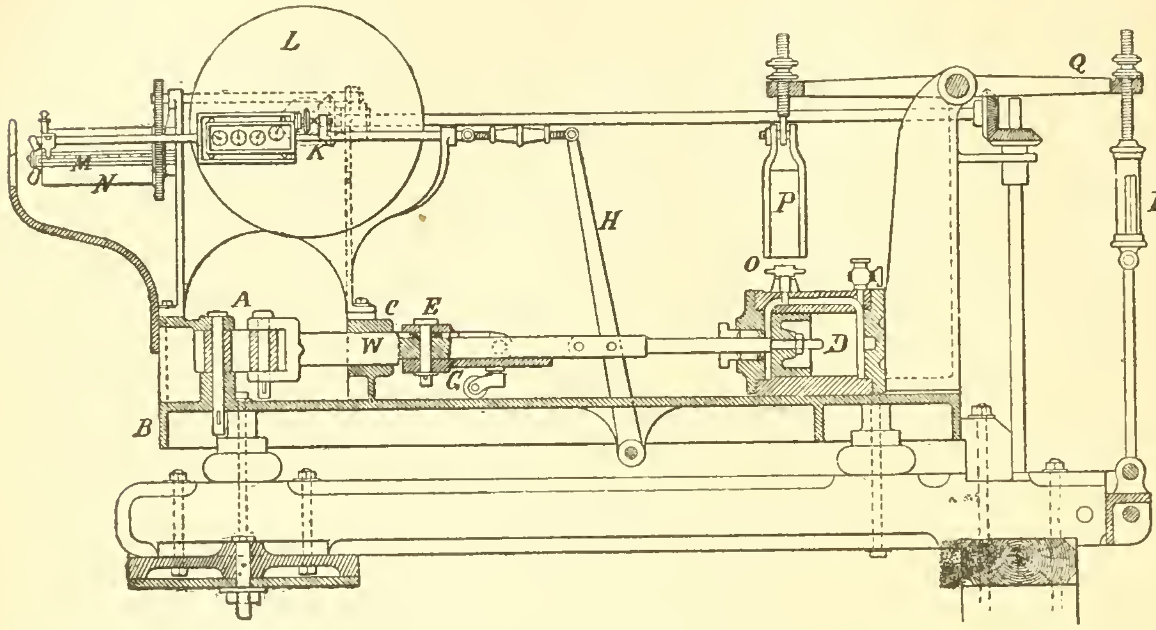


to a slide carrying an integrating disk *K* and a register, also an index on a scale *M* at the left, and a pencil for operating on a paper-drum *N*. The integrating disk *K* receives motion from an operating disk *L*, which in turn is revolved by connection with the hind axle. From the same train of gearing the paper-drum *N* is operated. To determine the weight ordinarily carried upon the shoul-

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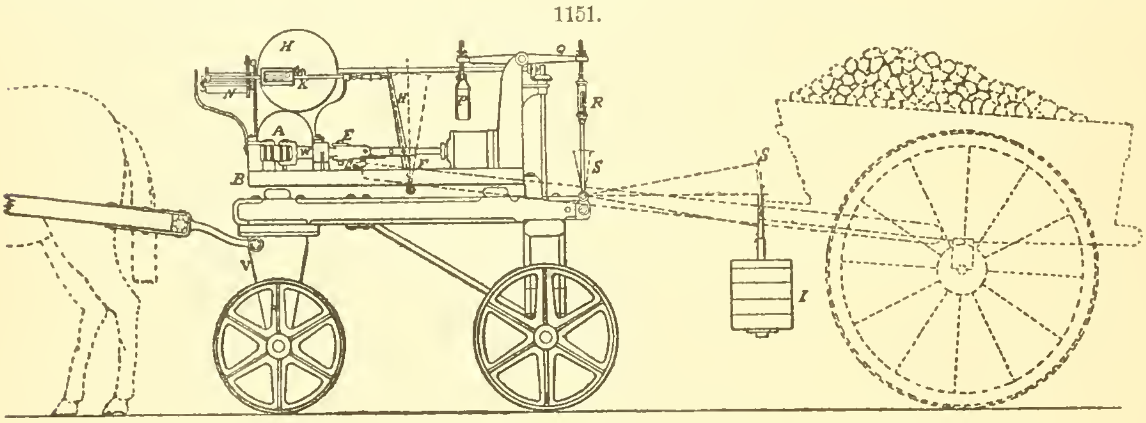
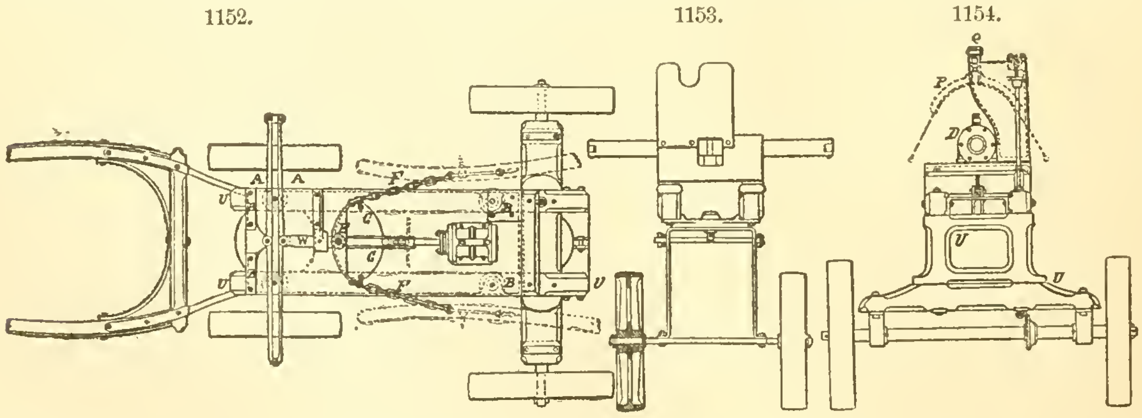



ders of a horse, the shafts are suspended from a yoke *P*, which is supported at one end of a lever *Q*, having at the other end the spring-balance *R*. The results are however modified by the vertical component of the tension on the yoke *G*. Springs of different resistances are provided for the apparatus, and provision is made to test the same in place by means of the bell-crank lever *S*

1152. 1153. 1154.



and weights *I*. Experiments made with this apparatus in the year 1874 (see *Engineering*, xviii., 33) show that ordinary wagons without springs constructed by different makers, with some differences in width of tires and inclination of wheels, required with one exception but 44 to 51 lbs. draught per ton of gross load carried on a road at a speed of about 2½ miles per hour. One wagon with

springs required but 33 lbs. draught per ton, showing a saving of 25 per cent. compared with a similar wagon without springs. The spring wagon showed no advantage in a field, where the draught of the various wagons varied from 188 to 229 lbs. per ton; the differences in this case being chiefly due to the widths of the tires, which varied from $2\frac{3}{4}$ to 4 inches, the latter of course sinking less into the soft ground. Two carts required 30 to 36 lbs. draught per ton of gross load hauled on the road at a speed of $2\frac{5}{8}$ miles per hour, and 140 to 143 lbs. per ton when on the field; the width of tires being $3\frac{1}{2}$ and 4 inches.

A dynamometer car, employed by MM. Vuillemin, Guebhard, and Dieudonné on railroads in France, contained very complete apparatus for measuring the resistance of railway rolling-stock under various conditions. A plan view of the springs employed is shown in Fig. 1155. It is composed of 14 bars of the shape shown, each 40.94 inches long and 2.08 inches wide, seven of which are connected at their centres to each of the draw-bars *A* and *B*, and the ends of the springs are connected by pins in plates *C* as shown. The bars *D D* carry chocks at the ends to limit the extreme movement of springs. By removing the pins from the two ends of plates *C* at the same time, the number of springs in action may be reduced. Separate scales are provided for each of the groups thus formed. The tables accompanying a report of the trials of this instrument show that it recorded tractions of upward of 18,700 lbs.

*Dudley's Dynograph* is an apparatus for the same purpose as the above, but with different details, which has been used on railroads in the United States.

*Duckham's Hydrostatic Weighing Machine and Dynamometer.*—Fig. 1156 represents a front view and Fig. 1157 a transverse section of the machine. From the latter it will be seen that the machine

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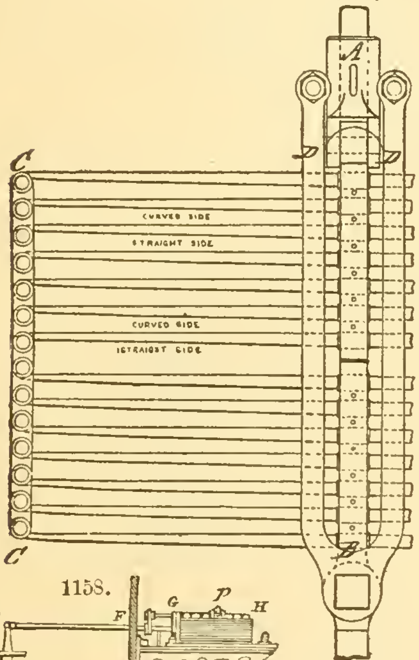


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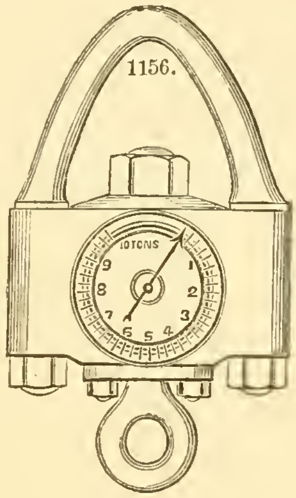


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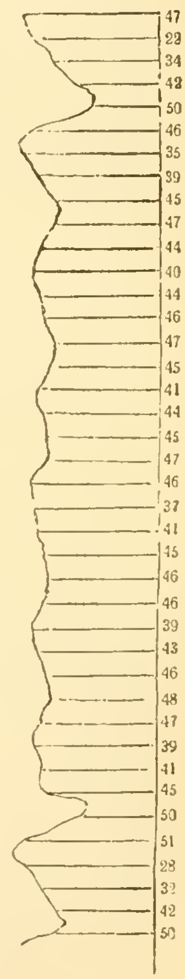


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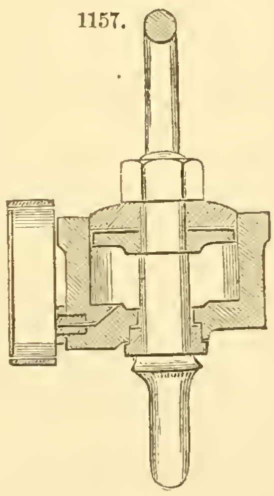

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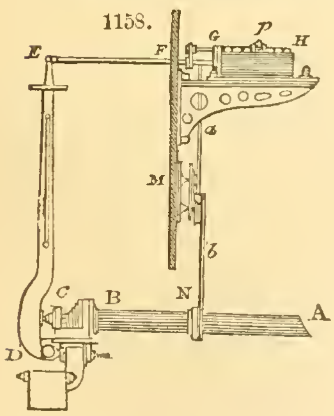


consists of a cylinder and piston, the latter kept tight with leather packing both in the piston itself and on the piston-rod. Attached to this cylinder is an ordinary metal gauge, which shows the pressure to which the fluid in the cylinder is subjected by the weight suspended from the piston-rod. It of course does not matter if there should be a slight leakage about the piston or rod, because as soon as the weight is suspended from the rod the leather packing becomes tight, and produces the same pressure on the fluid (castor-oil is generally used) in the cylinder as though no leakage had taken place. A peculiar merit of this apparatus is its lightness. A machine of 84 lbs. weight is capable of weighing 10 tons; and as soon as merchandise or other bodies are raised and suspended from it, the weight of the same is indicated on the dial. The machine can be used for weighing all kinds of goods, and affords a very convenient testing machine for bar-iron, wire, chains, cordage, etc. It can also be used as a dynamometer to ascertain the resistance of trains or vessels.

A displacement dynamometer has been suggested, in which the forces are to act to push a parallel plunger into a fluid, on the general principle of the Stiles steam-gauge.

*Dynamometer for Measuring the Thrust of a Screw-Shaft.*—This instrument, Fig. 1158, is merely

a lever, or a combination of levers, with the shaft pressing near the fulcrum, and the farther end of the lever, or combination, attached to a spring-balance. *A B* is the screw-shaft, pressing as it revolves against a movable pin, which presses against a knife-edge on the lever *D E*. The rod *E F* is connected with the spring-balance, which cannot be seen in the figure, being concealed by the cylindrical barrel *G H*. A slide attached to the rod *E F* has several grooves in it, so that the pencil *p* may be brought into contact with more than one part of the barrel if desired. The barrel is made to revolve by means of a belt *a b*, connecting it with the screw-shaft; and there are pulleys of different sizes connected with the bulkhead at *M* and the shaft at *N*, by which the motion of the cylinder can be regulated, and be made quicker or slower at pleasure.

When the engines are directly connected to the propeller, the thrust-bearing is made free to move longitudinally, and the levers are connected to it. A hydraulic regulating cylinder should be connected to the levers, to reduce the amplitude of the vibration of the spring. A diagram from a thrust dynamometer is shown in Fig. 1159. The mean ordinate may be obtained by either of the methods mentioned in treating of indicators. The diagram shown was taken in connection with two others, and the mean pressure of the three was found to be 41.309 lbs., which was multiplied by a system of levers so that the actual thrust was 8,086.4 lbs. The speed of the ship was 9.893 knots per hour, equal to (9.893 × 6,080 ÷ 60 =) 1,002.49 feet per minute; so the work per minute was (10,024.9 × 8,086.4 =) 8,106,535 foot-pounds, showing a development of (8,106,535 ÷ 33,000 =) 245.65 effective horse-powers. The indicated horse-power at the same time was 465.6; so the efficiency of the propelling machinery was (245.65 ÷ 465.6 =) 52.76 per cent., and (100 − 52.76 =) 47.24 per cent. was absorbed in resistances of various kinds, including the friction of the engine and shafting, the slip of the screw (represented by the water propelled aft), and the fluid resistance on the screw-blades. The efficiency is higher than has been obtained in many other cases, though the writer in a series of trials of the machinery of the U. S. Coast Survey steamer Blake found that the efficiency averaged as high as 56.22 per cent. The vessel had compound engines, and the screw, which was entirely submerged, had a fine pitch, and was of large diameter for the size of vessel.

A hydrostatic thrust dynamometer is made by running the screw-shaft through a cylinder and piston, so that the thrust will be borne by the piston, and the stress is computed from the reading of a gauge, as in the Duckham machine shown in Fig. 1156.

Rotary Dynamometers are of two kinds, absorbing and transmitting. In the former the power is

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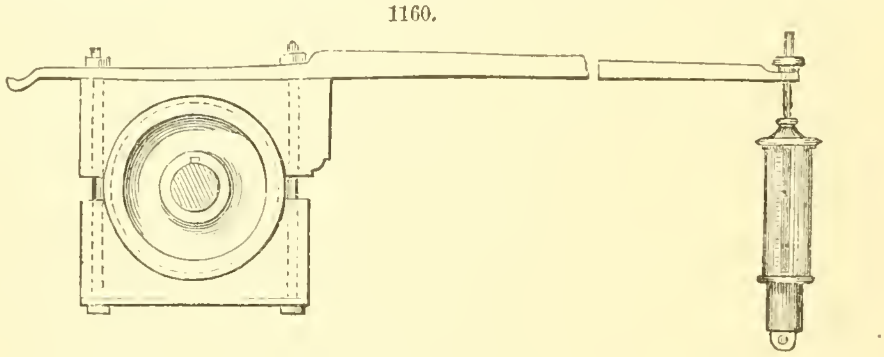

absorbed in friction during the act of measurement; in the latter it is simply transmitted through the instrument.

*Prony's Friction-Brake* is the basis of all absorbing dynamometers. The apparatus consists essentially of a clamp tightened upon a revolving pulley and tending to revolve therewith, but held in position by weights or springs representing the intensity of the effort. A simple form, consisting of a pair of wooden clamps tightened by bolts and connected through a lever to a spring-balance, is shown in Fig. 1160. Often, however, iron straps faced with wood are used, and held in position by weights, springs, or both, connected directly to the strap or an attached lever. When the clamps are tightened so that the weight is lifted, the surface of the pulley, moving with a known velocity, is regularly overcoming a resistance measured by the weight and strain on the springs, increased by the leverage if any; and the distance moved by the surface multiplied by such increased force represents the work done. The result would be the same if the radius of the pulley were increased to the point of application of the weight, and the work calculated from the actual revolutions and weights imposed. If $N$ = revolutions of shaft per minute, $R$ = the distance from the centre of shaft to a vertical line passing through the point of suspension of the weights, $W$ = weights imposed, including strain on spring if used, and $P$ = the horse-power developed; then

$$P = \frac{3.1416 \times 2\,R\,N\,W}{33000} = .0001904\ R\ N\ W.$$

To prevent extreme oscillations, a regulating piston in a cylinder filled with fluid is generally connected with some part of the lever; and it is usually necessary to apply water continuously to the surface of the pulley to absorb the heat developed by the friction.

*A Turbine Friction Dynamometer* is shown in Fig. 1161, which is applicable for use on any vertical shaft. It is an ordinary Prony brake in a horizontal position, acting upon the weights through a bell-crank. The regulating cylinder is shown applied to the end of the bell-crank lever opposite the weights. Pipes are also shown to conduct water to the surface of the pulley, the necessity of which is explained above.

*Froude's Dynamometer* is one of the absorbing type, designed for the use of the British Admiralty, to be applied directly to the shaft of a screw-steamer in place of the screw, as shown in Fig. 1162.

It consists of a disk-wheel resembling that of a turbine, with a large circumferential groove on either side opposite similar grooves in the casing. The grooves in both the wheel and casing contain curved inclined buckets, which act when the apparatus is immersed to throw water forcibly back and forth from the wheel and casing. The resistance produced tends to revolve the case, which is re-

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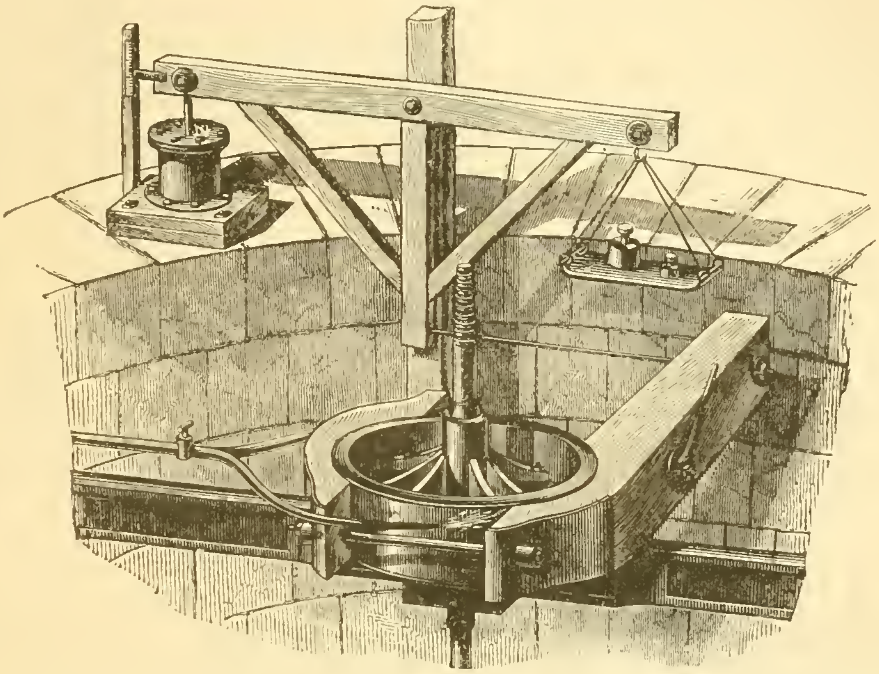
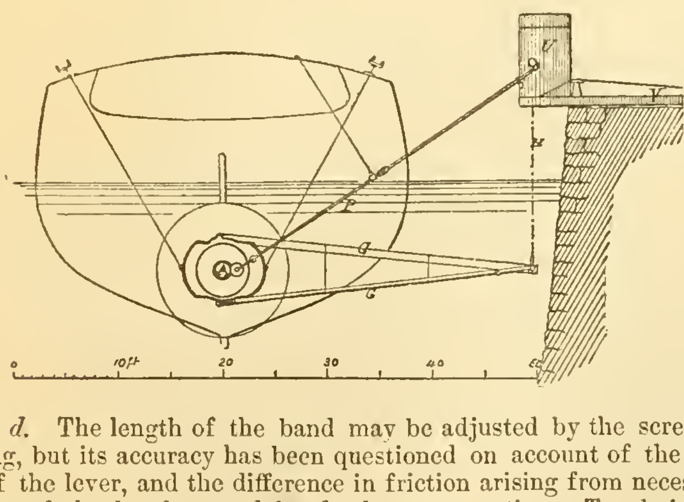


sisted by lever-arms *G G*, connected at their ends through a rod *H* with springs and recording apparatus on the wharf. Gates located in the projection on the side of the case are operated by gear connected with the inclined rods shown, to close off part of the area between the cavities in the wheel and case, and thus reduce the resistance as desired within large limits.

In using the ordinary friction-brakes, it is necessary to constantly adjust the screws tightening the clamps so as to lift the weights clear without striking a stop in the opposite direction. To avoid this, several brakes have been designed, in which the friction is regulated automatically. The simplest plan of doing this is shown in Fig. 1163, but is applicable only when the power to be controlled is small. A strap placed over a pulley is secured at one end to a spring-balance *c*, and loaded at the other with a weight *b*. The pulley turning in the direction of the arrow lifts the weight and reduces the tension on the spring-balance until the wheel turns in the band, when the force to be measured is shown by the difference between the weight *b* and the reading of the spring-balance *c*.

*The Appold Brake*, shown in Fig. 1164, consists of a strap lined with wood, with its ends secured to a lever *a f* at the positions shown, the upper end of the lever at *a* being held stationary. The action of the weight at *W* is to carry the bottom of the lever to the right and tighten the strap. The motion of the pulley in the direction of the arrow lifts the weight *W*, and carries the strap around until it becomes sufficiently loose to permit the pulley to turn on the brake. For instance, if connections to weight are properly arranged, the point of suspension *x* may move to *e*, when *f* would

1162.

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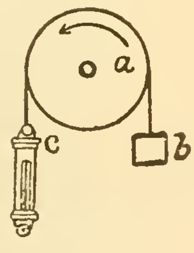
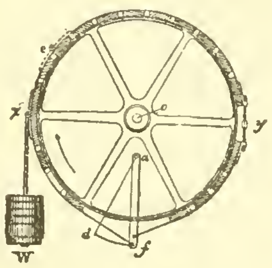


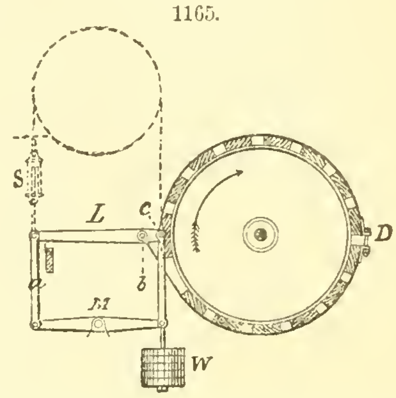

move to *d*. The length of the band may be adjusted by the screw *y*. This brake is perfectly self-adjusting, but its accuracy has been questioned on account of the neglect of the strain at the upper end *a* of the lever, and the difference in friction arising from necessary differences in tension on the two parts of the band, caused by the lever connection. To obviate this difficulty, Mr. W. Balk has designed a dynamometer in which a tightening-lever is placed horizontally opposite the connection to weights, and the end provided with a pan to receive small weights, which are varied as necessary to adjust the friction.

*A Friction Dynamometer* designed by Mr. C. E. Emery of New York is shown in Fig. 1165. One end of a friction-band is connected at the point *c* with the weight *W* and one end of a lever *L*. The lever receives at an intermediate point *b* a connection from the other end of the band, and is supported at the outer end *a* by a spring-balance *S* or one end of a lever *M*. First, supposing the lever *M* omitted, the weight *W* will tend to depress the lever *L* and strain the spring *S* (a stop shown being provided to prevent overstrain). When, however, the pulley revolves in the direction of the arrow, the weight and lever will rise until the tension is reduced, so that the pulley slips in the band. Putting $F$ = the force required to balance the load on the line from *c* to *W*, $W$ = the weight (including of course the permanent weight or preponderance), and *a*, *b*, and *c* the forces at the points *a*, *b*, and *c* due to the action of the spring-balance *S*; then the downward forces acting on the band = $W + c$, and the upward force = $b$. Hence $F = W + c - b$. But $b = a + c$; hence $F = W + c - (a + c) = W - a$. Therefore the force required to balance the load equals the weight less the tension on the spring-balance. The force represented by the latter may be subtracted automatically by adding another lever below *L*, provided with a central fulcrum on the bed-plate, and connected at the ends to the ends of the lever *L*; in which case the spring-balance would be omitted. The extra lever and connections, or a pulley and cord, may however be located above the lever *L*, as shown in dotted lines, and the balance either be retained or omitted as desired. During a preliminary run, the screw *D* in the friction-band should be adjusted to bring the lever *L* nearly horizontal, when the action of the apparatus will be absolutely automatic.

1164.




1165.

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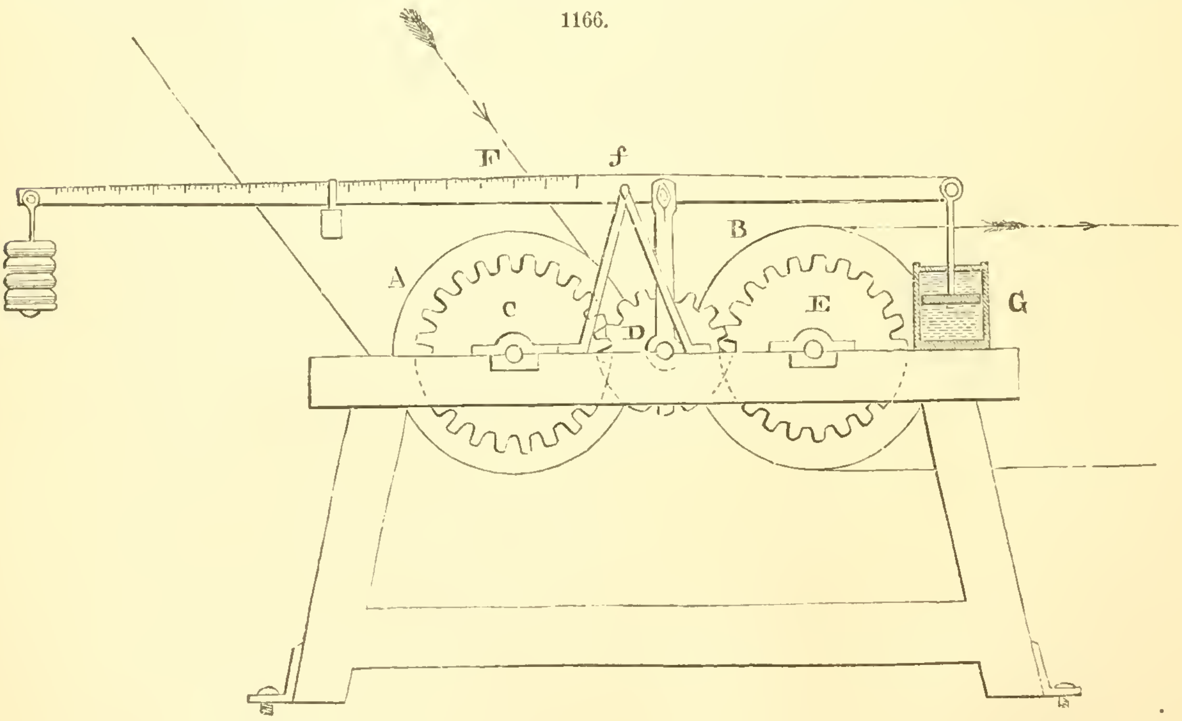
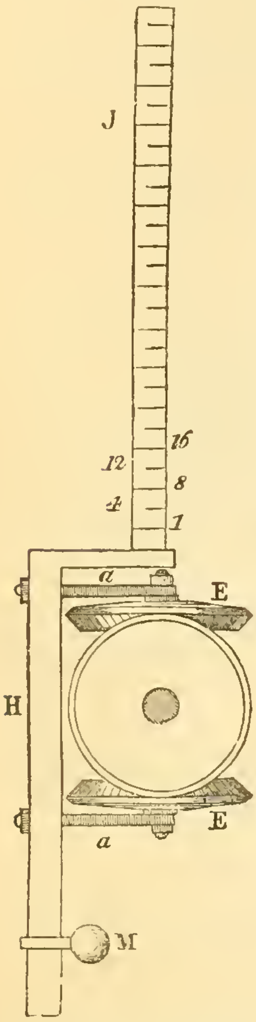



*A Transmitting Dynamometer* invented by Mr. S. Brown of Lowell is shown in Fig. 1166. The power is transmitted from a spur-gear *C* to another, *E*, through an intermediate gear *D*, the axis of which hangs in a stirrup supported by a steelyard *F*, the short arm of which is extended and connected to a regulating piston in the cylinder *G*, as shown. The force transmitted at the pitch-lines of the gears is the same on either side of the centre of pulley *D*, so that the strain communicated from the latter to the short arm of the steelyard is double that transmitted at the pitch-lines.

*The Bevel-gear Transmitting Dynamometer* shown in Figs. 1167 and 1168 operates upon the same general principle as that previously described. The power is applied to a bevel-wheel *D*, and is transmitted to another similar wheel *F* through bevel-gears *E E*, provided with bearings on a lever *J* turning on the shaft at *G*. The stress transmitted to the centres of the transmitting wheels *E E* is double that at the pitch-line, as in previous cases. As shown in Fig. 1167, the lever is bent from a

radial line to pass by the gears, and carries at the end opposite the scale a counterbalance weight $M$. On both sides of the machine are fast and loose pulleys. The fast pulley on the driving side $A$

1167.

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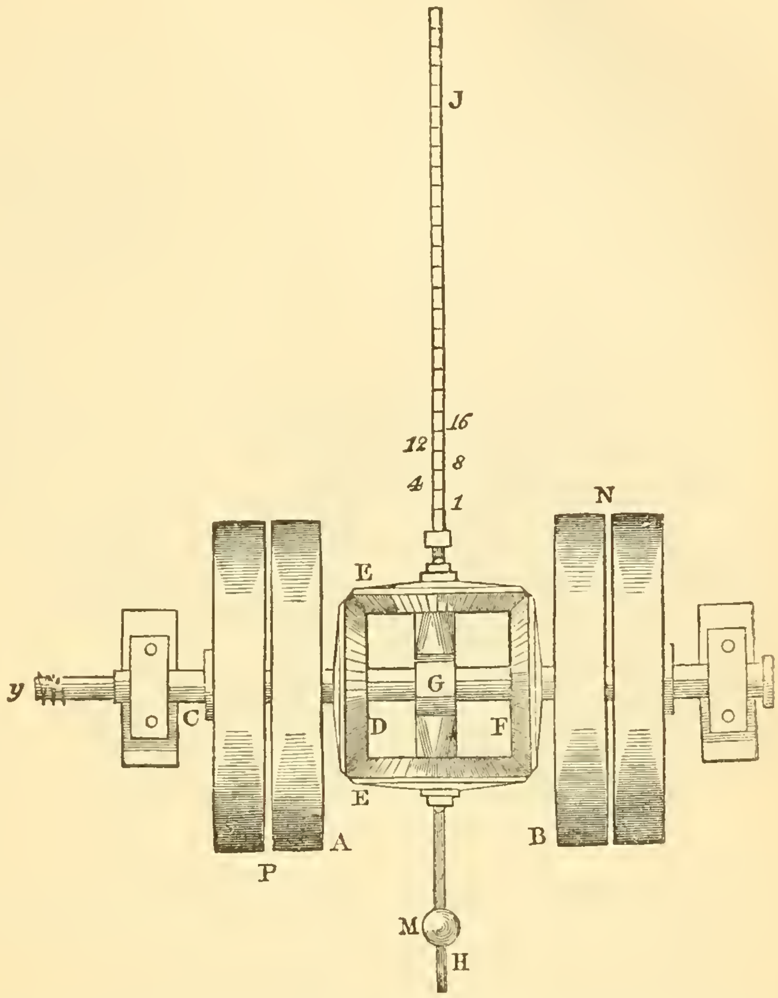


operates the bevel-gear $D$, and the corresponding gear $F$ on the opposite side operates the fast pulley $B$. By disconnecting a line shaft at the coupling and running a belt from pulleys on either

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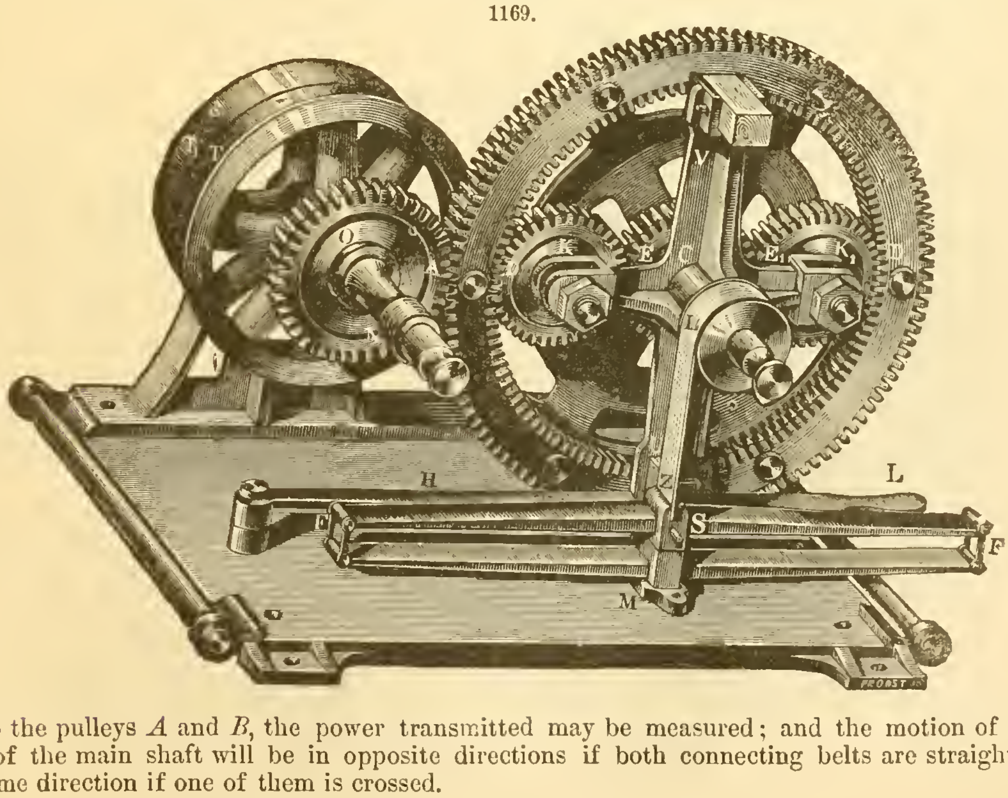


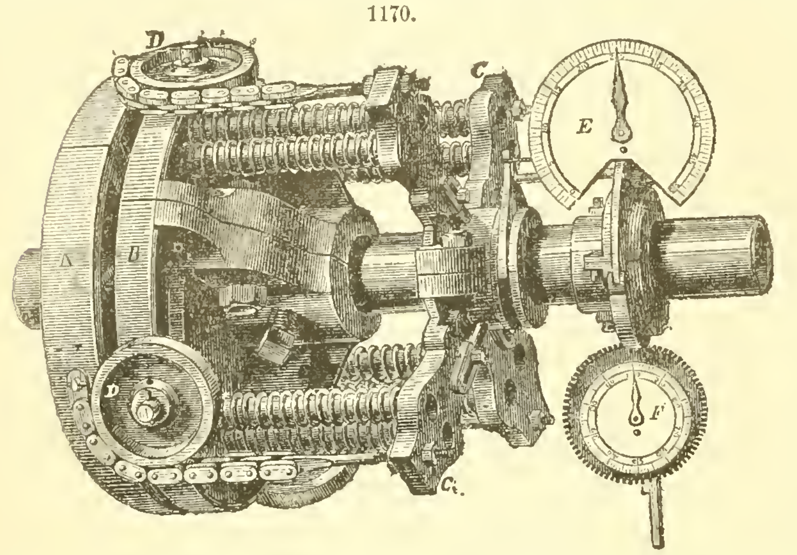

side to the pulleys $A$ and $B$, the power transmitted may be measured; and the motion of the two parts of the main shaft will be in opposite directions if both connecting belts are straight, but in the same direction if one of them is crossed.

In an improvement by Mr. J. B. Francis of Lowell, the motion on the side *B* of the machine is reversed by gearing to a second shaft, carrying a pulley from which a straight belt may be run to the main shaft without reversing the direction of its motion. There are also other improvements in details. The beam is balanced without the use of a movable weight *M*, and to this end a regulating piston is attached, as in Brown's machine. A register is operated by an endless screw on the extra shaft, and a bell strikes at every 50th revolution. The beam *J* is so graduated that the weight raised 1 foot high per second is obtained directly, by dividing the weight as shown on the beam by the number of seconds occupied by the shaft in making 50 revolutions. The friction of the machine was ascertained by the use of Prony's friction-brake placed on the extra pulley.

*A German Transmitting Dynamometer* is shown in Fig. 1169. The power is transmitted from a wheel *D* with internal gear to a central spur gear-wheel *E*, through opposite transmitting gear-wheels *K K* attached to arms on a sleeve carrying a pulley *L*, which through a band *Z* strains the dynamometer springs *F F*.

*Neer's Rotary Transmitting Dynamometer* is shown in Fig. 1170. The main shaft is disconnected at a coupling, on either side of which are secured the disks *A* and *B*. From the circumference of the disk *A*, which is the driving side, chains are carried around the pulleys *D* on the disk *B*, which chains tend to move a disk *C* parallel with the shaft, and compress the springs shown between disks *C* and *B*. The extent of this movement showing the transmitted stress is, by a fork in a slot on the hub of the disk *C*, transferred through a cord to a pulley on a shaft carrying an index which shows the stress on a dial *E*. This part of the apparatus is supported in a groove on a separate revolving boss, and part of the circumference of the latter is provided with an endless screw operating another index on a dial *F*, to show the revolutions. The dial frame is prevented from revolving by a cord attached to the lower arm shown. All the disks are made in halves, and the disks *A* and *B* are recessed to go over the coupling when desired, so that the apparatus may be applied in a very short time. The acting distance of the transmitted force is from the centre of the shaft to the centre of the chains.

1170.




In *Sutton's Dynamometer* lugs on the side of a driving disk operate upon spiral springs placed against similar lugs on a driven disk. The acting distance of the springs is slightly varied at different compressions, but the error is scarcely appreciable when the disks are large, and may in any case be corrected on the scale.

In *Emerson's Dynamometer* the revolving stresses are transferred to longitudinal ones by a system of levers, and the latter measured by a bent-lever balance. C. E. E.

EARTHWORK CUTTING. See Excavating Machinery.

ELECTRIC BELLS. Bells or gongs struck by hammers vibrated by an electro-magnet placed in an electric circuit. The apparatus and accessories consist of the bell, the push-button or circuit-closer, the conducting wire, and the battery. The battery may be composed of any of the constant elements described under Electro-Galvanic Batteries. For household purposes the Leclanché cell will be found excellently well suited, the number of elements used being regulated by the extent and consequent resistance of the circuit. The button or circuit-closer consists of two metallic strips *p* and *g*, Fig. 1171, placed one above the other. In its normal state the upper strip is separated from the lower one by a spring. To the strips *p* and *g* the conducting wires *a* and *c* are secured, and as the strips are separated the circuit remains open. It is closed when desired by pressing the knob *p'*. The button is inclosed in a wooden or rubber case. Fig. 1172 is a convenient device for combining a number of keys within a small compass. Eight push-buttons, corresponding to as many distinct circuits, are arranged at equal distances around a cylindrical case, within which the connections between the metallic strips and wires are made. Each wire is separately insulated by a silk covering, and all are made into a single strand as they leave the case.

The ordinary form of bell used for giving single taps is shown in Fig. 1173. It consists of an electro-magnet *M M*, opposite the poles *n s* of which is placed the armature with its clapper *k*. The latter in its normal position is held back from the bell *G* by a spiral spring attached to the movable upright *d*, which serves to regulate its tension. The stroke of the armature is limited by the set-screw *r*.

By a slight modification of the connections in the bell instrument, the apparatus can be used both as a vibrator and as an instrument to give single taps. The general plan is shown in Fig. 1174, in which *M* and *e* are the electro-magnet and armature. *S* is a switch which can be turned on *B* or *E* at pleasure. When it is on *E*, the apparatus becomes a vibrating instrument; when turned on *B*, there is no interruption of the current with the attraction of the armature, and the instrument simply responds by single taps to each closing of the circuit by the push-button. The path of the

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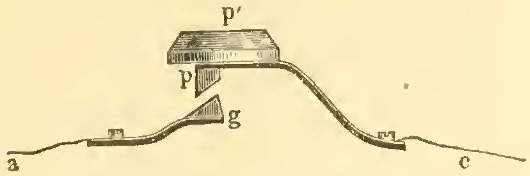


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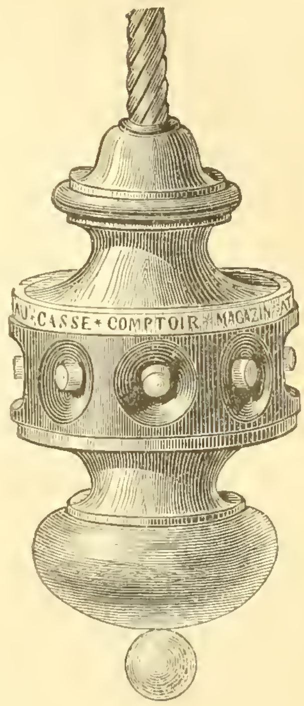


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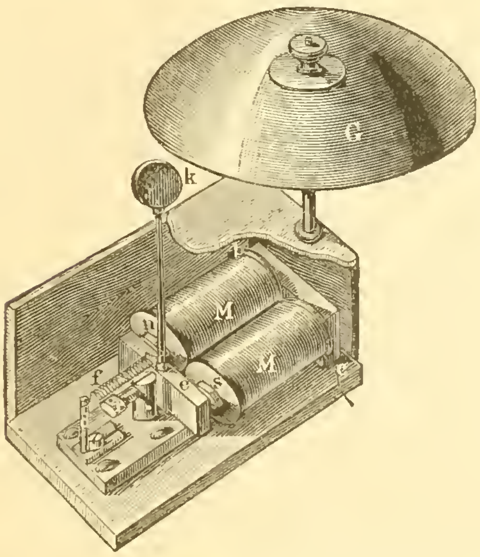
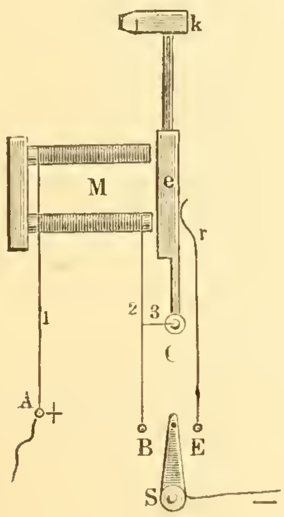



current, when the switch is on *B* and *E* respectively, is sufficiently evident from the figure without further description.

When it is desirable to produce a very loud sound, the double bells and double electro-magnets

1174.

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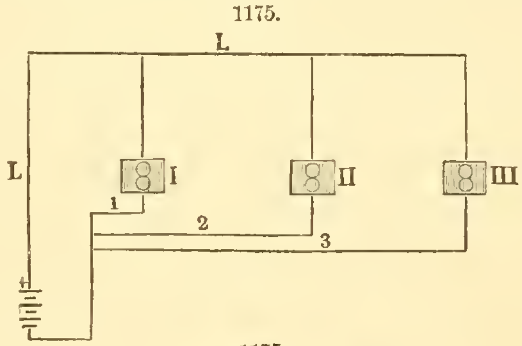


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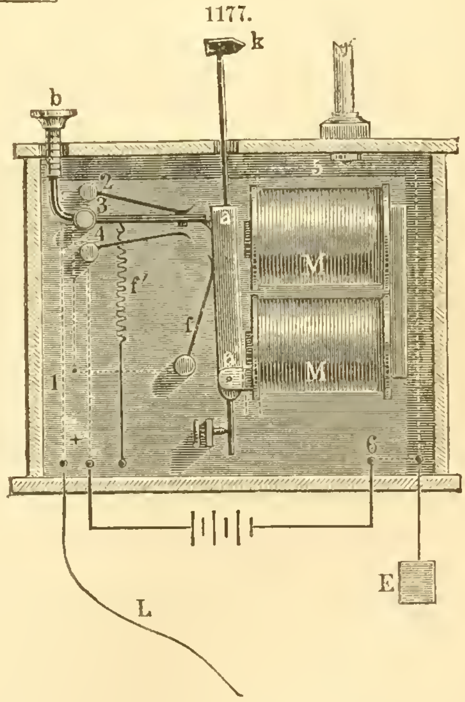


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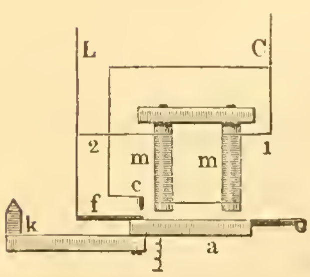



are usually employed in the vibrating apparatus. In general, the principle of all vibrating bells is that of the self-acting make and break; but, when the contacts are rigid points, the vibrations of

the armature take place only within narrow limits, and the arrangement cannot very well be utilized for ringing a bell. Siemens has devised a plan, in his dial instruments, which answers the purpose much better, by giving the armature a greater range of movement; but the adaptation of this device to the ringing of bells for simple calls is a little troublesome, and in fact, for general use, would be altogether too complicated. By far the most preferable way of obtaining the desired range of stroke is that already described, in which a spring of some kind forms part of the path for the current, and which, with the attraction of the armature, follows the latter for such a distance as may be required.

When one battery is to serve for operating several of the bells above described, the vibrators can not all be placed in one circuit, as each one interrupts the circuit independently of the others; and it is impossible, or rather impracticable, to make the armatures of the various instruments so that they will all vibrate in exactly the same time, or always be in unison. The plan generally adopted for such cases is shown in Fig. 1175, where each bell, *I*, *II*, *III*, has a separate conducting wire of its own, as represented by the numerals 1, 2, 3, and a return wire, *L L*, serves for all. If, now, one of the bells is operated by the pressure of a push-button in 1, 2, or 3, as the case may be, it acts without in any way interfering with the others, as they are all quite independent of the circuit thus interrupted.

The fault just noticed in connection with the vibrating armature, causing a break at each vibration, may be remedied in a very easy manner simply by causing the armature to cut its own magnet out of circuit after each attraction. The principle works very satisfactorily, and will be readily understood by reference to Fig. 1176. *m m* are the coils of the electro-magnet; *a*, the armature, to which the clapper *k* is attached by means of a rather stiff spring; and *f*, an elastic steel spring, which readily follows the to-and-fro movement of the armature for a short distance. As will be seen, a current arriving at *C* passes through the wire 1, coils *m m*, and wire 2, to the line *L;* the armature is thus attracted to the spring *f*. The forward movement of the armature brings the spring *f* against a contact *c*, and forms the shunt quite independent of the armature. As the resistance of this route is exceedingly small compared to that of the helices, almost the entire current passes by the new path, and the cores become demagnetized. The retractile force of the spring now preponderates, and the armature falls against the back stop, breaking the shunt circuit on its way. As this arrangement does not break the main circuit, any desired number can be placed in the same line and worked without interfering with each other.

When the bell system is to be used for long distances, or when a very loud ringing is desired, for which purpose the main line current, as a rule, is not sufficient, a relay and local battery are generally used; and with the heaviest apparatus, requiring still more power, the ringing is done by means of weights. Fig. 1177 represents an arrangement devised by Aubine, in which a single set of electro-magnets, *M M*, serve both for the relay and the call. A small projection on the upper end of the armature *a*, when the latter is in its normal position, supports the lever 3, keeping it from making contact with spring 4, and at the same time holding it firmly against spring 2. When now a current is sent into the line, it passes along the connection 1 to spring 2, thence to lever 3 and its connecting wire to spring *f* and armature *a*, and from there on through the coils to earth. This causes an attraction of the armature; lever 3 falls down on spring 4 and closes the local circuit, which again results in a magnetization of the core. The armature is thus made to vibrate in the manner already described, and a violent ringing is set up, which continues until, by pressure on the knob *b*, lever 3 is again raised and supported by the armature projection. (See "The Speaking Telephone, Talking Phonograph, and other Novelties," Prescott, New York, 1879, from which the foregoing is abridged.)

ELECTRIC CLOCK. See Watches and Clocks.

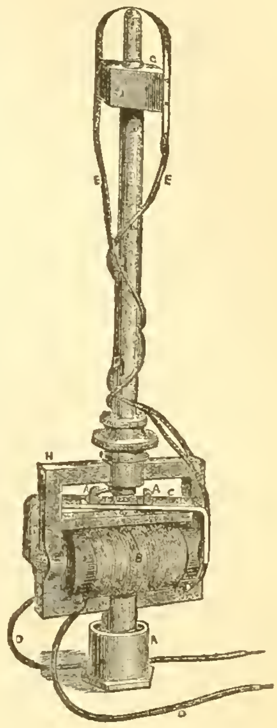
ELECTRIC ENGRAVING MACHINE. A machine for engraving the cylinders of copper or brass employed in printing woven fabrics and paper hangings. (See Calico-Printing.) The current is used to determine, by means of electro-magnets, the slight simultaneous advance or withdrawal of any number of engraving diamond-points from the varnished surface of the copper rollers to be engraved, according to the position of a corresponding metal contact-point on the non-conducting surface of a prepared pattern. The pattern and cylinder to be engraved are moved mechanically in concert, and the proportion of their relative movements can be varied by mechanical adjustment. The engraving points have a slight vibrating action given to them, which scratches off the varnish whenever brought into contact with it, and produces a series of fine zigzag lines, which facilitate the retention of the pasty coloring matter used. The prepared pattern determines the moments at which this contact occurs; and the concert between the movements of the pattern and the roller produces a similar agreement between the pattern and the figures engraved, which may clearly be made larger or smaller than the pattern in any desired proportion and in any required number. The copper when exposed is afterward etched by an acid bath.

ELECTRIC FUSE. See Blasting, and Fuses.

ELECTRIC GAS-LIGHTER. Numerous devices have been invented for the ignition and regulation of street gas-lamps by electricity, the current not only lighting the gas, but, by means of an electro-magnet, turning on or off the supply. One of the most successful contrivances for this purpose is that devised by Mr. St. George L. Fox of London, and represented in Fig. 1178. The socket *F* is screwed on to the top of the gas-pipe, and the frame *H* is made hollow, for the purpose of allowing the gas to flow up to the nipple at the summit. The gas is turned on or off by means of a valve or stop-cock, the lever of which is seen caught by one of the studs *A*. The two studs *A A* are borne on the upper part of the permanent horseshoe magnet *C*, the latter being supported on the point of a fine pivot working in a cross-piece in the frame *H*. This permanent magnet is capable of a reciprocating horizontal movement; and supposing its position in the drawing to be reversed, the other stud *A* would carry the pin or lever back through a short space. This shifting of the lever one way or the other serves to turn the gas either on or off, as may be desired. The movement of

the magnet is effected by a change in the polarity of an electro-magnet consisting of a soft-iron core in a coil at *B*. According as the current is sent forward or backward through the coil, so the polarity of the core is altered, and the permanent magnet is turned on its pivot. The electric current which turns the gas on or off is obtained from the magneto-electric machine at the station, and is conveyed by the wire *D D*, which wire connects all the lamps. Supposing the current to be sent in such a direction as to turn the gas on, the next operation consists in transmitting along the wire *D D* a powerful discharge obtained from a condenser raised to an electromotive force of several thousand volts or units by means of a Ruhmkorff coil. Around the primary coil at *B* is wound a secondary coil of fine wire, and of much greater length. The discharge from the condenser has the effect of producing a secondary current along the wire *E E*, thereby developing a small spark just over the burner. The discharge which passes through the primary wire has the same effect simultaneously on the secondary wire in all the lamps of the circuit, so that, the gas being previously turned on in the manner described, the whole of the lamps are lit. If the first and last lamp in each circuit be in sight of the station, the continuity of the circuit will be proved by the lighting of these two lamps. When it is required that the lamps shall be extinguished, a reverse current through the primary wire will cause the permanent magnet to turn on its pivot and strike the lever of the stop-cock, so as to turn off the gas. The stop-cock consists of a brass tube forming a vertical socket, and fitting into the cylindrical part above the horseshoe magnet. The socket thus formed has a small aperture on one side, opening into the hollow of the frame *H*. The plug of the cock is made with a very slight downward taper, and is hollowed out in the middle. At the side of the plug is an aperture corresponding to that in the socket. When the aperture of the plug is thus brought opposite the aperture in the socket, the gas flows up toward the burner; and, in like manner, when the plug is so turned as to remove its aperture from coincidence with that of the socket, the gas is intercepted, and the supply turned off.

1178.



ELECTRICITY. According to the modern theory of correlation and conservation of forces, electricity is a mode of motion of the molecules of matter. "Light, heat, electricity, magnetism, motion, are all convertible material affections. Assuming either as the cause, one of the others will be the effect. Thus heat may be said to produce electricity, electricity to produce heat; magnetism to produce electricity, electricity magnetism; and so of the rest." (Grove.)

The general science includes statical and dynamical electricity, or electric force in a state of rest or of motion. Statical electricity, being usually developed by friction, is often called "frictional electricity." The other terms above noted, indicating the development of the force by heat, chemical action, magnetism, etc., may be classed under the general title of dynamical electricity. This, in whatever way produced, is always in the form of currents, and exhibits a constant manifestation of power. Statical electricity may also be obtained by greatly increasing the intensity of dynamical electricity.

The term electro-dynamics is commonly used to include the whole branch of electrical science which deals with the effects of electricity in motion. In making general reference to the subject, the separate topics comprised in which will be found treated under headings below noted, we here deal only with mechanical effects, or, in other words, with electrical work.

The word *potential*, as technically employed, strictly indicates a condition for or tendency to do work. For brevity it is used alone to denote the difference between the electrical condition of a given body or point and that of the earth, which is assumed as zero. The work * done in unit of time in the part of an electric circuit lying between two given points is equal to the strength of the current multiplied by the difference of potential between these points. It may be added here that, if the direction of the current is from a point of higher potential to a point of lower potential, work is done *by the current;* whereas, if the current flows from a point of lower to a point of higher potential, work is done *in maintaining the current.* We know, however, that if, starting at any point A of an electric circuit and following the direction of the current, we arrive at a point B of lower potential, we shall, by continuing to follow the current, get back again from the point B to the point A; that is, we shall pass from a point of lower to a point of higher potential. Consequently, since the strength of the current crossing any complete section of a circuit is the same, it follows that the net amount of work done *by* the current in any part of a circuit is equal to the net amount of work done in the remainder of the circuit *in maintaining* the current. The different kinds of work which the electric current can do may be classified as follows:

A. The work done by a current of constant strength, traversing a circuit no part of which undergoes change of position relatively to another part or to any other conducting circuit or magnet, is entirely *internal;* that is, it appears within the conductors of which the circuit is made up, in one or other of the following forms: (1.) As development of heat, in metallic conductors of one material. (2.) As development of heat accompanied by transfer of heat causing inequality of temperature, in metallic conductors not all of one material. (3.) As development of heat together with chemical decomposition, in a conductor consisting of a compound liquid.

B. When the strength of a current varies, or when the position of the circuit relatively to other

* Abridged from a paper on "Electrical Apparatus" by Professor G. Carey Foster, F. R. S, in "Hand-Book of South Kensington Loan Collection," 1876.

conductors or to magnets is changed, more or less work may be done in the production of effects external to the circuit in addition to some internal work of one or more of the above kinds. The external work may be of any of the following kinds: (4.) Magnetic induction; that is, the development of the magnetic condition in substances susceptible of magnetism. (5.) Production of induced currents in other conductors. (6.) Production of mechanical work through the motion of magnets or of conductors conveying currents.

The laws according to which the action (1) takes place were first ascertained by Joule (1841). The effect referred to under (2) was discovered by Peltier (1834), and has since been investigated chiefly by Edlund (1870–'71). The laws of the chemical action of the current (3) were established by Faraday (1833). The magnetizing power of the current (4) was first observed by Arago (1820); and the production of induced currents (5) by Faraday (1831). The existence of mechanical force between electric currents and magnets, capable of doing work by changing their relative position, was discovered by Oersted in 1820; and in the same year Ampère discovered that there is a mechanical force between two currents or two parts of the same current. From the laws according to which he found that this force is exerted, he deduced the conclusion that a closed electric circuit has the properties of a magnet, and showed that any magnet might be replaced by a system of circulating currents.

Most of the effects produced by an electric current are connected with the direction of the current, in such a way that they are inverted when the direction of the current is inverted. Thus, when a current passes from a piece of bismuth into a piece of antimony, heat is absorbed; but when it passes from antimony to bismuth, an equal quantity of heat is evolved. When a current passes between two platinum plates immersed in water, decomposition takes place, and oxygen is evolved at the plate by which the current enters the water, and hydrogen at the plate by which it leaves; inversion of the current inverts the chemical action. Again, a current encircling a piece of soft iron renders it magnetic, and if the current is inverted the magnetization is reversed. Lastly, if motion is produced by the mutual action of a current and a magnet, or of one current on another, the inversion of the current causes inversion of the motion. The only two cases in which the effect of a current is independent of its direction are the development of heat in a homogeneous conductor, and the force exerted by one part of a current upon another part of the same current. The distinction between the former (reversible) class of effects and the latter (non-reversible) is connected with the fact that the work expended in a given time in producing any of the former class is simply proportional to the strength of the current, whereas in the case of the latter class of effects it is proportional to the square of the current-strength. A further distinction is that, if any reversible effect which a current would produce by traversing a conducting circuit in a given direction is caused by external agency, a current is generated in the circuit. Thus, by supplying heat at certain points of a circuit composed of alternate pieces of two different metals, and withdrawing heat at certain other points, a (thermo-electric) current is produced in the same direction as that which would have caused heat to be absorbed at the first set of points, and to be evolved at the second set. Again, if the chemical action which a current in a given direction would produce in a compound liquid is produced by other means, the result is a current in the same direction, provided the liquid makes part of a conducting circuit. Similarly, work done in causing changes of magnetization in the neighborhood of a conducting circuit, or changes in the position of magnets or currents relatively to the circuit, causes the circuit to be traversed by a current opposite to that which would have produced the changes in question. On the other hand, no current is produced by either supplying heat to, or taking heat from, any homogeneous parts of a conducting circuit, nor by moving one part of such a circuit relatively to another part. In fact, all the various methods by which electric currents can be produced are processes in which some reversible effect of such currents is brought about by the expenditure of external energy.

The applications of these principles will be found under Electric Bells, Electric Gas-Lighter, Electric Light, Electric Machines (Static), Electric Pen, Electro-Ballistic Machines, Electro-Galvanic Batteries, Electro-Magnets, Electro-Metallurgy, Electrometers, and Electromotors.

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York, 1875; "Electricity, its Theory, Sources, and Applications," Sprague, London, 1875; "Traité de l'Electricité Statique," Mascart, Paris, 1876; "Magnetism and Electricity," Guthrie, London, 1876; "Electricity and the Electric Telegraph," Prescott, New York, 1877. *On Special Applications:* "Exposé des Applications de l'Electricité," Du Moncel, Paris, 1856; "L'Electricité et les Chemins de Fer" (discussion of systems proposed for prevention of accidents by aid of electricity), De Castro, Paris, 1859; "Electromagnetismus," Dub, Berlin, 1861; "Les Merveilles de la Science," Figuier, Paris, no date; "The Forces of Nature—Applications of the Physical Forces," Guillemin, translated by Lockyer, New York, 1873; "Electrical Testing," Kempe, London, 1876. For works on telegraphy, see TELEGRAPHIC APPARATUS. *Tables, etc.:* "Electrical Tables and Formulæ," Clark and Sabine, London, 1871; "Experimental Physics" (construction of apparatus), Weinhold, translated by Loewy, London, 1875.

ELECTRIC LIGHT. There are four methods of converting electricity into light. I. By means of two carbon conductors, between which passes a series of intensely brilliant sparks, which form a species of flame known as the *voltaic arc*. II. By means of a rod of carbon or kaolin, a strip of platinum or iridium, or various other substances, placed between conductors and rendered luminous by incandescence due to the heat caused by the resistance of the material to the current. III. By means of the stratified discharge of the electric current *in vacuo*, or in tubes containing various gases. IV. By means of a quick succession of the "extra sparks" due to the sudden rupture of a current flowing through a conductor of considerable length.

I. THE VOLTAIC ARC LIGHT.

This is the commonest as well as the oldest form of electric illumination. The amount of light yielded depends upon the intensity of the current, the nature of the electrodes, and the medium which surrounds them. The color of the light varies with the material of which the electrodes are composed, or according to the presence of various metals. It is yellow with sodium, white with zinc, green with silver, etc. The shape of the arc depends on the form of the electrodes. With a positive coke point and a negative platinum plate, it is conical; between two carbon points, it is ovoid. The maximum length of the flame depends on the intensity of the current. Despretz determined in 1830 (1) that the length of the arc augments in more rapid ratio than the number of elements employed to produce it, and (2) that this increase is more marked for small than for larger arcs. Thus, the arc produced with 100 Bunsen elements is nearly quadruple that produced by 50 elements; that resulting from 200 elements is not triple that from 100, and the light from 600 elements is 7½ times greater than the arc from 100 elements. (3.) When the elements are coupled for quantity, the length of the arc increases less rapidly than the number of elements. The arc from 100 elements, measuring 25 millimetres, increases to only 69 millimetres with 600 elements coupled in 6 series of 100 each; while with the same battery of 600 elements coupled for tension (see ELECTRO-GALVANIC BATTERIES), it reaches a length of 183 millimetres. (4.) When the positive pole is underneath, the voltaic arc is shorter than when the negative pole takes this position. With 6 series of 100 elements coupled for quantity, a length of 74 millimetres is obtained when the positive electrode is uppermost, and 56 millimetres when it is beneath. (5.) When the electrodes are placed horizontally, the arc is shorter than with vertical electrodes; but then the quantity battery is more advantageous than one coupled for tension. Thus, 6 series of 100 elements coupled in quantity give a horizontal arc 40 millimetres in length, while if coupled for tension the same battery produces an arc only 27 millimetres long. These experiments show plainly the difficulties in the path of constructors of dynamo-electric machines adapted to the production of the electric light, when such machines yield currents of great quantity and low tension.

The following useful formulæ relating to the electric light have been deduced by Mr. Desmond G. Fitzgerald:

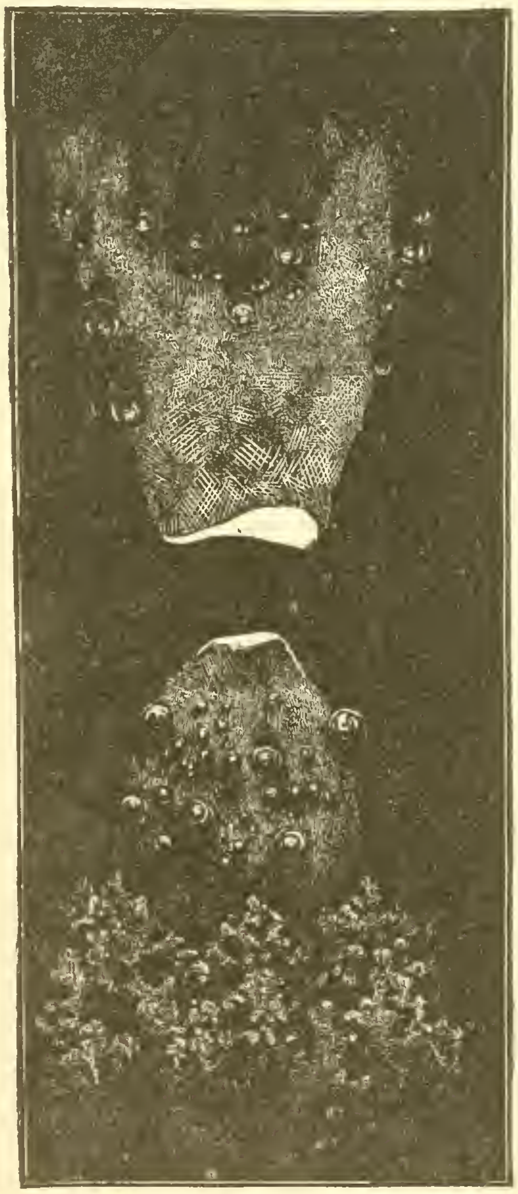
Let $E =$ the electromotive force, in volts, acting in a circuit; $R =$ the total resistance, in ohms, of the circuit; $r =$ the resistance of the voltaic arc obtained; $H.P. =$ the horse-power of the prime motor used to work the dynamo-electric machine; and $h.p. =$ the horse power absorbed in the production of electrical work. The energy of the current, or the mechanical equivalent of the work and heat produced by it per hour, will be $W = \frac{E^2 \times 2654}{R}$ foot-pounds $= \frac{E^2 \times 1.18}{R}$ foot-tons. The horse-power absorbed in the current $\left(\frac{\text{energy in foot-pounds}}{33000 \times \text{time in min.}}\right)$ will be $h.p. = \frac{E^2}{R \times 747}$. The ratio $\frac{h.p.}{H.P.}$ is the measure of the efficiency of dynamo-electric machines. In the case of Gramme's machine, under the best conditions, we have $H.P. = h.p. \times 1.39$. The horse-power absorbed in the arc itself is $h.p. \times \frac{r}{R}$. The ratio of this latter value to $h.p.$, or $\frac{h.p. \times r \times 747}{E^2}$, is the measure of the efficiency of the electrical circuit in the production of the greatest quantity of light with a given quantity of electrical energy. In the experiments with Gramme's machine made by the Committee of the Franklin Institute, the light produced by the voltaic arc, in standard sperm candles, was $h.p. \times \frac{r}{R} \times 1048$ (candles); or, calling $I$ the current in vebers per second, the light in this case was $I^2\, r \times 1.4$ (candles). This may probably be taken as a safe minimum value for small lights; but it would appear that the quantity of light increases more rapidly than the square of the current, or that the light is most economically produced when it is least subdivided. With the larger magneto-machines, worked with greater horse-power, the constants for the two latter formulæ would be in fact considerably higher, provided one light only be obtained.

From the foregoing it will also be seen that the diminution according to the "square," and not according to simple proportion, applies to electricity just as it applies to light, heat, sound, gravita-

tion, and other physical phenomena. Thus, if a circuit be divided into two branches whose resistances are equal, a current of half the strength passes through each branch, producing at the point of resistance, not half the light, but only a quarter, because the effect follows the square of the current-strength. If the current had been divided into three equal branches, in each branch only one-ninth part of the original light would be obtained, and so on; so that if an electric light of 1,000 candles were divided into 10 equal lights, the result would be 10 lights of 10 candles each, in place of one of 1,000 candles. When the light is produced by the second of the above-named systems—that is, by incandescence—a still greater loss is occasioned. M. Fontaine has shown that under the most favorable circumstances, with a Bunsen battery of 48 cells, 8 inches high, the diminution of the subdivided light was so great that, where he put 5 lights in one circuit, he only obtained a total illuminating power of a quarter of a burner, with 4 lamps only three-quarters of a burner, with two lamps 6½ burners, and with one lamp 54 burners. These numbers give the following ratio: 1, 3, 8, 26, 216, thus showing how rapidly the light diminishes when divided. With the voltaic arc, however, and with the same battery, he was able, by a Serrin lamp, to obtain a light of 105 burners.

The Voltaic Arc is produced by the incandescence of a jet of particles detached from the electrodes and projected in all directions. This projection takes place chiefly from one pole to the other, or more particularly from the positive to the negative pole. The positive electrode has a much higher temperature than the negative, and its rate of consumption during a given time is double that of the latter. The arc is approximately represented in Fig. 1179. On each of the carbons appear scattered liquid and incandescent globules due to the mineral substances contained in the electrodes. These do not appear when the carbons are chemically pure. To sum up, the voltaic arc is a portion of the electric circuit having all the properties of other portions of the same circuit. The molecules passing over from point to point constitute a mobile chain, more or less conducting and more or less heated, according to the intensity of the current on one hand, and to the separation and nature of the electrodes on the other. The results are the same as if the electrodes were connected with a metallic wire or a rod of carbon of small section, so that it will be seen that the light produced by the voltaic arc and that obtained by incandescence is due to one and the same cause, namely, the heating of a resisting body introduced in the circuit.

1179.



The Carbons, when in stick form, usually vary in diameter between from three-sixteenths of an inch to nearly 1 inch; probably about three-eighths of an inch is the size most generally employed with the power of the lights used for industrial purposes. Their exact diameter should be proportioned to the strength of the current employed. The nature of the carbon point formed during combustion will soon show whether the due proportion is observed or not. A long tapering point should be corrected by a large carbon, while a blunt flat-headed one indicates an excess of the combustible, at least with alternating-direction currents. The carbons are composed of the material (graphite) which is deposited on the inside of gas retorts, which is ground up very finely, washed, and a certain proportion of molasses is added to cause the particles to adhere more firmly together. The mass is then passed into a mould, and afterward dried and finished. Sometimes also a proportion of salts is added, such as soda, potash, strontium, etc., to increase certain properties of the carbons during combustion, either their duration or their luminosity. Again, the carbons in some cases after being finished are metallized exteriorly; that is, a thin layer of copper, nickel, or other metal is chemically deposited on the outside. The resistance offered to the electric current, in its passage to the carbon point, is thus diminished by its being partly conducted along the copper, instead of having to force its way through the carbon only.

In order to adapt the voltaic arc, which for brilliancy is only exceeded by the sun itself, to practical uses of illumination, it is necessary that its radiance should be rendered continuous. This is impossible so long as the two carbons are immovably adjusted point to point; for, as the positive electrode wastes away twice as fast as the negative electrode, the distance between the points increases continually, until it becomes so great that the current will no longer leap over it. Then the lamp is extinguished, and to relight it the points must again be brought into contact and readjusted to the proper distance. Ordinarily this would have to be done every few minutes, so that almost the first problem which presented itself to inventors was the devising of some automatic arrange-

ment which would render the carbons self-adjusting. This apparatus is termed the *regulator*. The duty to be performed by these contrivances is summed up as follows by Mr. J. H. Shoolbred in a paper read before the British Association in 1878 (see *Engineering*, xxvi., 362):

"1. The regular and gradual approach of the carbons according to rate of combustion; and, therefore, a progress varying not merely with the strength of the current, but also with the nature of the supply, whether in one continuous direction or whether alternating in direction. 2. The approach or separation of the carbon points to create the electric spark in the first instance, and then to counteract the ever-varying irregularities of the strength and supply of the current during the period of illumination; and also to prevent these irregularities being felt beyond the lamp itself (a most important and essential point where several lights exist on one circuit). 3. The normal separation of the carbons according to the desired length of the voltaic arc, which is deemed suitable to the strength of the current employed. The first-named duty is generally performed, in most apparatus, either partly or wholly by gravity, which necessitates the carbons being placed over one another. In some of the most recent forms, however, the carbons can be placed horizontally, or in any other position, and either in a direct line opposed to each other, or inclined toward one another, their approach being performed by mechanical action. The second set of duties are carried out almost universally by means of electro-magnets and armatures, etc., contained generally in the base of the apparatus. The third duty is performed ordinarily by adjustment-screws placed on the attachment of the carbon-holders, and which can be made to raise or depress the carbons at will, even during the period of illumination."

1. Lamps using Carbon Points.—*Foucault's Regulator.*—One of the earliest and most ingenious forms of lamps is that of Foucault, which is represented in Fig. 1180. $L'$ is a barrel driven by a spring inclosed within it, and driving several intermediate wheels which transmit its motion to the fly $o$. $L$ is the second barrel, driven by a stronger spring, and driving in like manner the fly $o'$. The racks which carry the carbons work into toothed wheels attached to the barrel $L'$, the wheel for the

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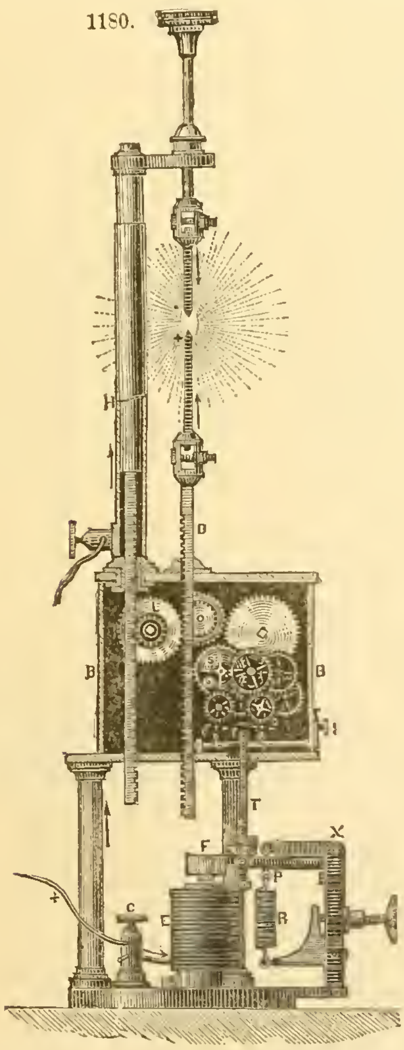

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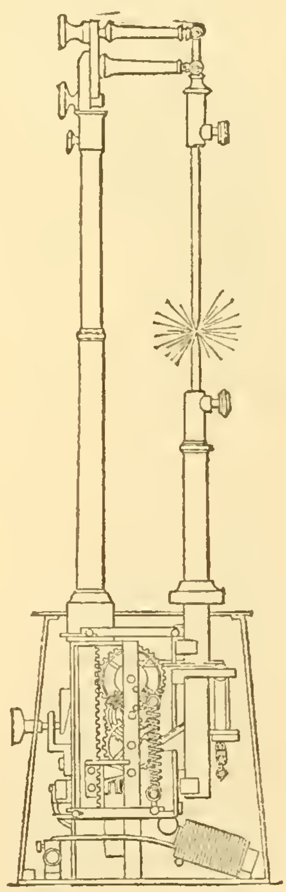

positive carbon having double the diameter of the other. The current enters at the binding-screw $C$, traverses the coil of the electro-magnet $E$, and passes through the wheel-work to the rack $D$, which carries the positive carbon. From the positive carbon it passes through the voltaic arc to the negative carbon, and thence, through the support $H$, to the binding-screw connected with the negative pole of the battery. When the armature $F$ descends toward the magnet, the other arm of the lever, $FP$, is raised, and this movement is resisted by the spiral spring $R$, which, however, is not attached to the lever in question, but to the end of another lever, pressing on its upper side, and movable about the point $X$. The lower side of this lever is curved, so that its point of contact with the first lever changes, giving the spring greater or less leverage according to the strength of the current. In virtue

of this arrangement, which is due to Robert Houdin, the armature, instead of being placed in one or the other of two positions, as in the ordinary forms of apparatus, has its position accurately regulated according to the strength of the current. The anchor $T\,t$ is rigidly connected with the lever $F\,P$, and follows its oscillations. If the current becomes too weak, the head $t$ moves to the right, stops the fly $o'$, and releases $o$, which accordingly revolves, and the carbons are moved forward. If the current becomes too strong, $o$ is stopped, $o'$ is released, and the carbons are drawn back. When the anchor $T\,t$ is exactly vertical, both flies are arrested, and the carbons remain stationary. The curvature of the lever on which the spring acts being very slight, the oscillations of the armature and anchor are small, and very slight changes in the strength of the current and brilliancy of the light are immediately corrected.

*Serrin's Regulator.*—Where single lights only are desired from a machine, the Serrin lamp, Fig. 1181, is most commonly used. In this the carbons are placed vertically over one another, the upper

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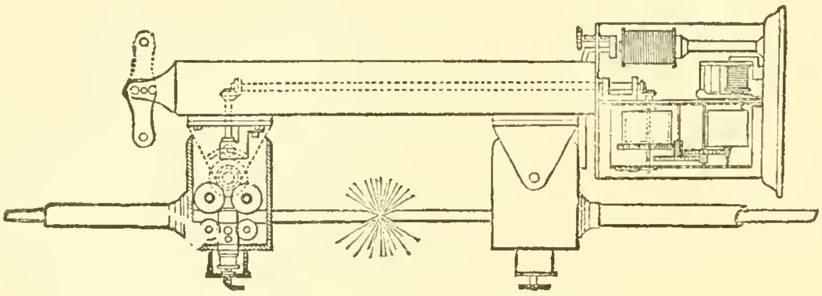

carbon being made to travel by means of a rack and pinion attached to the bottom of its holder, and driven by a spring which is controlled by an electro-magnet placed in the base of the lamp. This electro-magnet, according to the force of the current passing into it from the main current, also attracts or rejects an armature, the effect of this oscillating movement being to cause the lower carbon-holder to rise or fall, according to the irregularities in the strength of the main current, which is itself producing the voltaic arc. The normal separation of the carbon points to suit any required length of arc is effected by raising or depressing the upper carbon-holder, by means of the screw placed at the top of its upright, where the horizontal arm is hinged.

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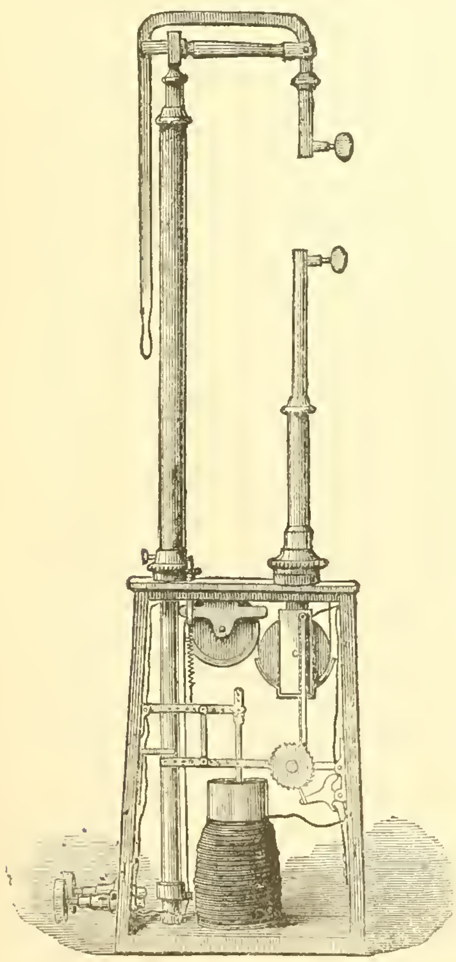

*The Brush Regulator* has a helix of insulated wire, which is a core partially supported by adjustable springs. A rod passes through the core, and at its lower end holds the carbon pencil in a clamp. The axial magnetism produced in the helix by the passage of the current draws up the core, and, by means of a lifting finger, raises one edge of a washer, which by its angular impingement against the rod clamps and lifts it to a distance controlled by an adjustable stop, but separating the carbon points just far enough to produce the light. As the carbons burn away, the increased length of the electric arc increases its resistance and weakens the magnetism of the helix, and therefore the coil-rod and carbon move downward by the force of gravity, until by the shortening of the arc the magnetism of the helix is strengthened, and the downward movement arrested. (See "Report of a Committee appointed to Test Dynamo-Electrical Machines," *Journal of the Franklin Institute*, 3d series, vol. lxxv., Nos. 5 and 6.)

*The Lontin Regulator.*—M. Lontin has introduced two forms of regulator, which have the two advantages of being independent of any particular position (the action of gravity being entirely dispensed with), and of allowing any length of carbon to be used, and of providing therefore for any ordinary period of illumination without the necessity of a fresh supply of carbons. In one of these regulators the travel of the carbons is effected by means of two endless screws with threads in opposite directions, one to each carbon-holder, which are thus caused to progress; the action of an electro-magnet causes these screws to revolve when required to do so. In the other regulator, the Mersanne, Fig. 1182, an electro-magnet causes a round bar to revolve, which runs lengthwise with the carbons, which motion is imparted by means of beveled gearing to small wheels at the extremity of which the carbon-holders revolve, and so propels the carbons gradually forward. These carbon-holders are fixed at about 2 inches from the carbon point, and the resistance which each current has to encounter is limited therefore to that due to this length, irrespective of that of the carbon.

*The Maxim Regulator.*—Mr. H. S. Maxim has devised several forms of electric lamps, of which one of the simplest is represented in Fig. 1183. Both carbon-holders are supported by a cord. As the upper or positive holder descends, it draws the cord over a pulley and raises the negative just one-

half the distance traveled by the positive. When the wires are properly connected and the carbons are in position, the top holder may be allowed to run down until the two carbons meet. This establishes the circuit and excites the axial magnet in the bottom of the case, when the core is drawn into the helix, and the two carbons, through the medium of levers, are drawn apart until the magnetism and tension of the spring balance each other, and as the carbon is burned away the arc is lengthened and the magnetism reduced; when the core is drawn out of the spool, thus feeding the carbons together as they are consumed until the parts have reached a position where the ratchet on the lower lever is beyond the reach of the pawl, then the core descends and the ratchet revolves, when the carbons take a new position, and the feeding goes on as before. The ratchet-wheel is prevented from turning more than one tooth at a time by a spring at the end of the lower lever. The pull of the rack is opposed to the spring; and when the pull is reduced by the disengagement of a ratchet-tooth, the lever, and with it the ratchet, are forced downward, and the succeeding tooth is caught on the pawl. The core on which the magnetism operates is connected with the rack by compound levers, so that by changing the position of the connecting link the leverage can be readily adjusted. Adjustments may also be made with the thumb-nut on the top of the case, which is attached to a retractile spring.

2. Lamps using Carbon in various Forms.—It will be noticed that all the lamps hitherto described employ carbon rods, the voltaic arc passing from point to point. Numerous other devices have been invented in which the carbon is otherwise arranged, or is used in different forms.

*The Rapieff Regulator.*—This apparatus, Fig. 1184, uses continuous-direction currents, thereby

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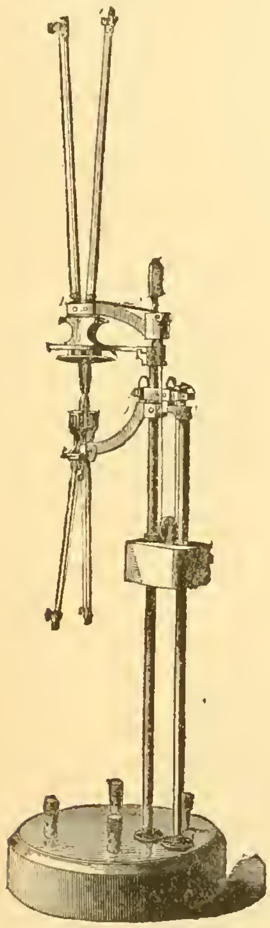

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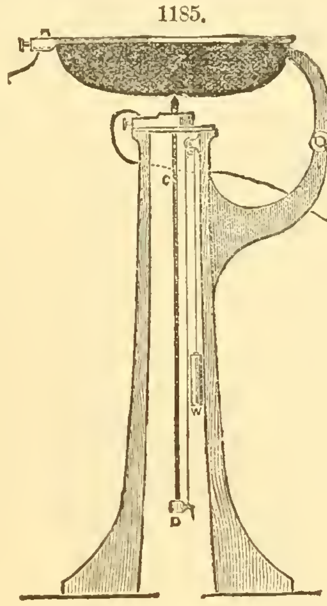

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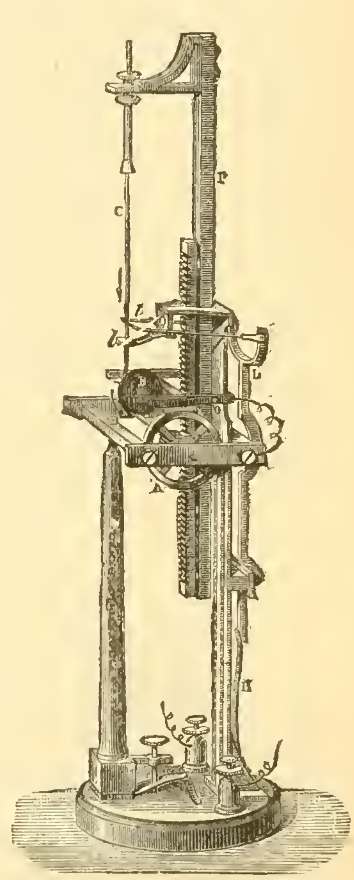

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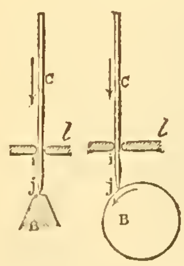


dispensing with the use of a second or distributing machine. Each carbon is, as it were, split in two lengthwise, and the halves placed relatively to each other in the form of a V, approaching each other only at the point of illumination. Each of the carbons passes through a holder, with a small guiding wheel, at a point about 2 inches from the luminous point, whatever the entire length of the carbon. As it is at this point that the electric current enters the carbon, the total resistance the former experiences in its passage to the luminous point is due to the intervening 2 inches of carbon only, irrespective of the entire length of the latter. This resistance is therefore uniform throughout the entire time of combustion. The gradual progression of the carbons toward the luminous point, as required by the rate of combustion, is effected solely by the intervention of gravity, the mechanism being operated by the descent of a small weight. Arrangements are provided for causing the necessary closing up of the carbons to produce lighting, and an improved safety apparatus is embodied, the object of which is to have a second light in reserve, which shall be automatically set alight by the current, if the first one should from any cause be extinguished.

*The Werdermann Lamp*, Fig. 1185.—In this one electrode consists of a large bun-shaped disk of carbon *C*, supported in the bracket *B*, and placed with the rounded face downward. The other carbon is a fine rod of carbon *c*, the upper end of which is in contact with the centre of the lower surface of the disk. This rod is supported by means of a spring collar, which also forms the circuit

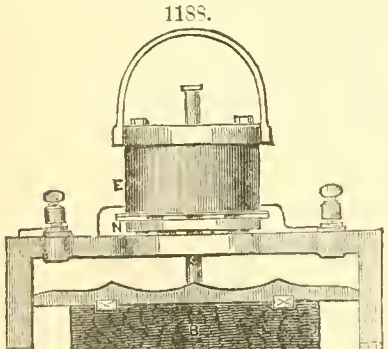
connection. This is within about three-quarters of an inch of the top of the carbon, so that this length becomes incandescent, and, the contact between the two carbons being only a point, a small electric arc is produced between the electrodes, while the electricity is at the same time passed on through the carbon disk, and the connections there attached to the next lamp. A cord connects the clasp $D$ at the bottom of the rod and the balance weight $W$, by which the rod is maintained in contact with the disk. Round the upper part of the disk is a metal band $A$, to which the circuit wire is attached, and the current thus passed on to the next lamp. (See *Engineer*, Nov. 1, 1878.)

*Regnier's Electric Lamp.*—In this system, which will operate in free air, the renewal of the carbon is progressive. The pencil, incandescent at one part of its length, proceeds almost continuously until completely used up. The principle of the construction is shown in Fig. 1186. A cylindrical or prismatic pencil of carbon, $C$, is traversed between $i$ and $j$ by an electric current (continuous or alternate) sufficiently intense to render it incandescent in this portion. The current enters or passes out through the contact $l$; it passes out or enters through the contact $B$. The contact $l$ (which is elastic) presses against the carbon laterally; the contact $B$ touches it at the extremity. Under these conditions, the carbon wears away at its extremity faster than at any other point, and tends to shorten. Consequently, if the carbon $C$ is urged forward continuously in the direction of the arrow, it will advance gradually in proportion as it wastes away, sliding through the lateral contact $l$ in such a way as to continually touch the terminal contact $B$. The heat developed by the passage of the current through the pencil is greatly increased by the combustion of the carbon. In practice, the fixed contact is replaced by a revolving contact $B$, which carries off the ashes of the carbon. The rotation of the terminal contact is made to depend on the progressive movement of the carbon, so that the latter acts as a check on the motive mechanism of the lamp.

An improved form of one of these lamps is represented in Fig. 1187. In this the rotation of the revolving contact is obtained by the pressure of the carbon on the circumference of the disk. By this means the end of the incandescent pencil never leaves the revolving contact, thus avoiding any cause for inequality in the light. The check, which is indispensable, is obtained as follows: The wheel $B$ is borne at the extremity of a lever which articulates at $O$. The pressure exercised by the carbon on the wheel $B$ causes the shoe $S$ to rub on the felly of a smooth wheel $A$, which is turned by the descent of the heavy rod $P$ through the medium of its rack and pinion $a$. According as the point of the luminous conductor presses more or less on the wheel $B$, the check prevents to a greater or less degree the descent of the column $P$, the advance of which is imperceptible.

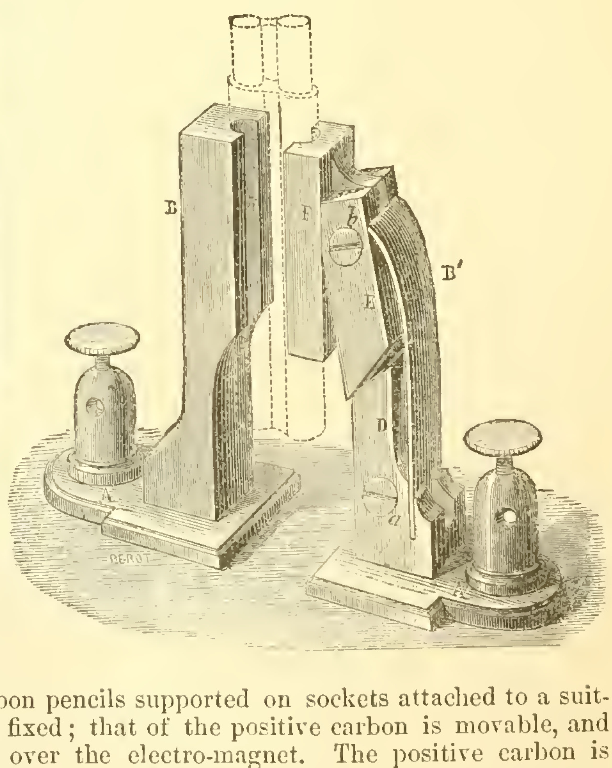
*The Wallace Lamp*, represented in Fig. 1188, consists of two plates of carbon, $A$ and $B$, of which $A$ is fixed and $B$ is connected with the armature of a small electro-magnet. The two plates are joined up to the opposite poles of the machine. When no current passes, the electro-magnet has no effect, and the upper plate falls till it rests upon the lower plate. On a current being sent through the system the electro-magnet attracts the armature, and thus raises the upper carbon. The distance through which this motion takes place can be adjusted as required; and as the time occupied by the combustion along the length of carbon is considerable, constant adjustment is unnecessary. The diagram will give a better idea of the lamp than any explanation. The manner in which it acts may,

1188.




1189.


1189 A.




however, be explained. The electric arc being started at any point, the flame gradually pasess along the length of the carbons as the material is burnt away. If it were possible to make two plates with rigidly parallel edges, the current, if it passed at all, must pass along the whole edge at once. Practically this state of things is impossible, and there is always a point of least resistance where the arc commences.

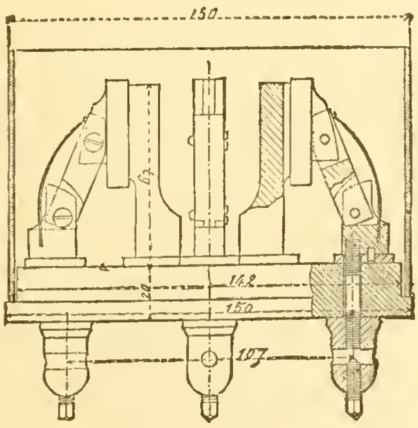
*The Weston Lamp.*—This consists of two carbon pencils supported on sockets attached to a suitable base. The socket of the negative carbon is fixed; that of the positive carbon is movable, and has attached to it an armature which extends over the electro-magnet. The positive carbon is pressed toward the negative carbon by a spring, and it is drawn away by the action of the magnet on the armature as the current increases in strength. When the current weakens, the reverse occurs. The negative carbon has twice the area of the positive to insure the equal burning of the two pencils, and it has a longitudinal groove in which is cemented a stick of lime, glass, or other material that may be vaporized at a high temperature.

Numerous other regulating devices are in existence, but sufficient have been presented to exhibit the principal forms.

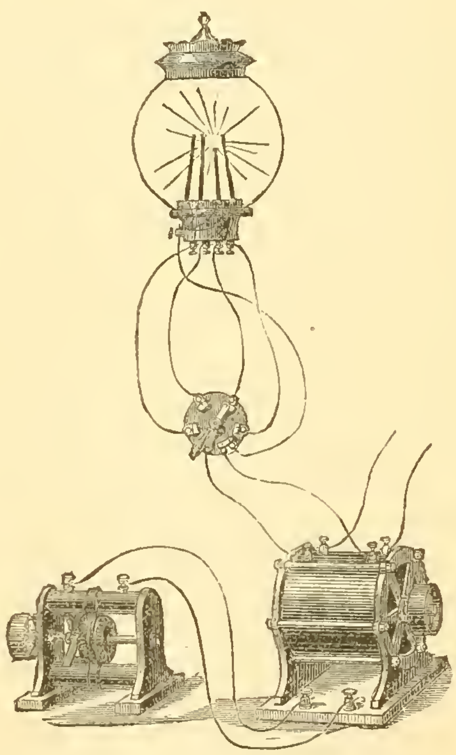
The Electric Candle.—This is the invention of M. Jablochkoff, and is one of the most important discoveries made in electric illumination, inasmuch as it obviates the use of any regulating contrivance, and enables several pairs of carbon rods to be supplied with current from a single source of electricity. The so-called candle, which is represented in part in Fig. 1189, consists of two cylindrical pencils of compressed carbon, 8.865 inches long and .157 inch in diameter. These pencils are placed side by side about .118 inch apart, and are connected together mechanically, but insulated electrically by a layer of plaster of Paris. The lower ends of the pair of carbons or "candle" so formed are imbedded in a mass of composition for giving to it solidity, and a little metallic plate for making electrical contact with its holder or "candlestick" is attached to each pencil, there being one on each side of the candle. In order to establish the light, one of the pencils is placed in metallic connection with one electrode of the dynamo-electric machine, and the other pencil with the other pole; and when the arc is once established at the top of the candle, it will continue to be produced as long as the machine is at work and until the candle is consumed. To the top of the candles is affixed a piece of composition formed of powdered plumbago and gum. This is shown at $A$, $C$ $D$ being the carbon pencils and $B$ the insulating material. It will be noted that the essential principles involved in the Jablochkoff candle are the placing the carbons side by side, so as to form a two-wicked electric candle, and the employment of an insulating substance between them, which gradually loses its resistance as high temperatures are reached. It is to this latter quality of the insulators employed that is due the success of the Jablochkoff system in dividing the electric current over a number of lights.

The arrangement by which the candles are held consists of a pair of brass jaws, $B$ and $F$, Fig.

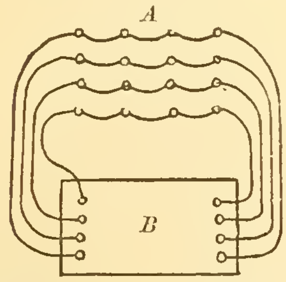
1190.



1190 A.



1190 B.




1189 A, insulated from one another, each having a semi-cylindrical vertical groove in its face to receive the candle, which in the figure is represented in dotted lines. The jaw $B$ is rigidly fixed to the base-plate $A$, to which is attached the attachment-screw connected with the positive electrode of the machine, while the jaw $F$ is jointed to the bracket $D$, which is attached to, and is in metallic connection with, the attachment-screw $A'$. By this jointed arrangement the clip can receive and hold firmly candles of sizes varying within certain limits, and by means of the spring $B'$ a firm pressure is maintained between the brass jaws and the metallic plates attached to the carbon pencils. The terminal screw $A'$ being connected to the negative electrode of the machine, the circuit is complete as long as the arc continues to be produced. Instead of connecting the screw $A'$ direct to the machine, it may be connected to a second candle-holder, and that to a third, and so on in series. In the Avenue de l'Opéra, and in the other places in Paris illuminated by the Jablochkoff light, the lamps were arranged in groups, each group being illuminated by one circuit.

Fig. 1190 is a sectional elevation of the arrangement for holding the candles in the lanterns used for street-lighting purposes in Paris. It is necessary to have four candles in order to carry on the illumination for the time required, as each candle lasts but an hour and a half. Only one candle burns at one time in each lamp, and when this becomes nearly consumed the circuit is switched from it to a new circuit, until the four have been burned, by which time the hour for extinguishing the street lights is reached. The holders are attached to a slab of white onyx and surrounded by a globe of opal glass.

Fig. 1190 A shows the lantern with its four candles, the switch, and the Gramme dynamo-electric machines used to supply the current (see Dynamo-Electric Machines). Full details of the apparatus,

and also of an automatic switch for shifting the current from one candle, will be found in *Engineering*, xxvi., 125.

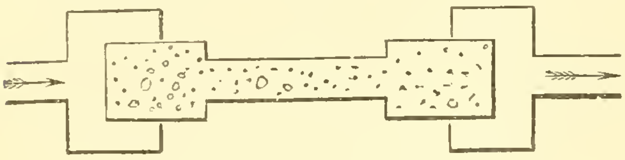
Fig. 1190 B shows the mode of connecting several sets of lamps, *A*, in circuit with one machine, *B*.

II. Electric Light by Incandescence.

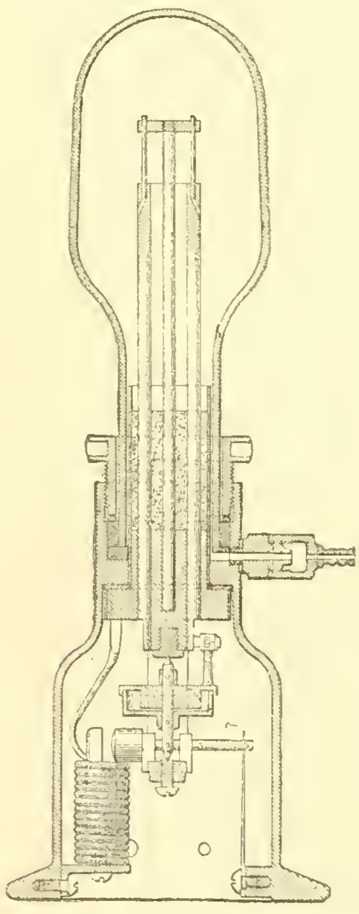
The first electric lamps in which an incandescent carbon rod was used was patented in England by King in 1845. His invention was based on the use of metallic conductors or continuous carbons heated white-hot by the passage of an electric current. The best metal for this purpose he found to be platinum, and the best carbon that from gas retorts. On account of the great affinity of carbon for oxygen when at a high temperature, it was found necessary to protect it from air and dampness, and to this end the carbon was inclosed in a glass vessel whence the air was exhausted.

*Lodyguine's Lamp.*—In 1849 Petric patented a lamp in which iridium in a state of incandescence was employed, small rods of the metal about 2 centimetres in length being used. Until 1874 no important improvements were made; but in that year M. Lodyguine obtained a grand prize from the St. Petersburg Academy of Sciences for a lamp which consisted of a single stick of carbon, inclosed in a hermetically sealed glass chamber from which all air has been exhausted, and into which an azotic gas which does not combine with carbon at a high temperature, such as nitrogen, is admitted. When the current from a magneto-electric machine, such as Wilde's, Gramme's, or Noble's, is passed through this carbon, it gradually gets heated to a white heat, and emits a brilliant and at the same time soft and steady light. Fig. 1191 shows the form of the carbon used; the light is given off at the narrow central part. The advantages claimed for this plan are, that there is a continuous circuit, so that any number of lights may safely be joined up in series to form one or more lamps; the lights can be made as small as desired, the flame is continuous and not injurious to the eye, and the current can be strengthened or weakened at will. It burns well under water, and has been proposed for illuminating dangerous mines, there being no fear of explosion from it.

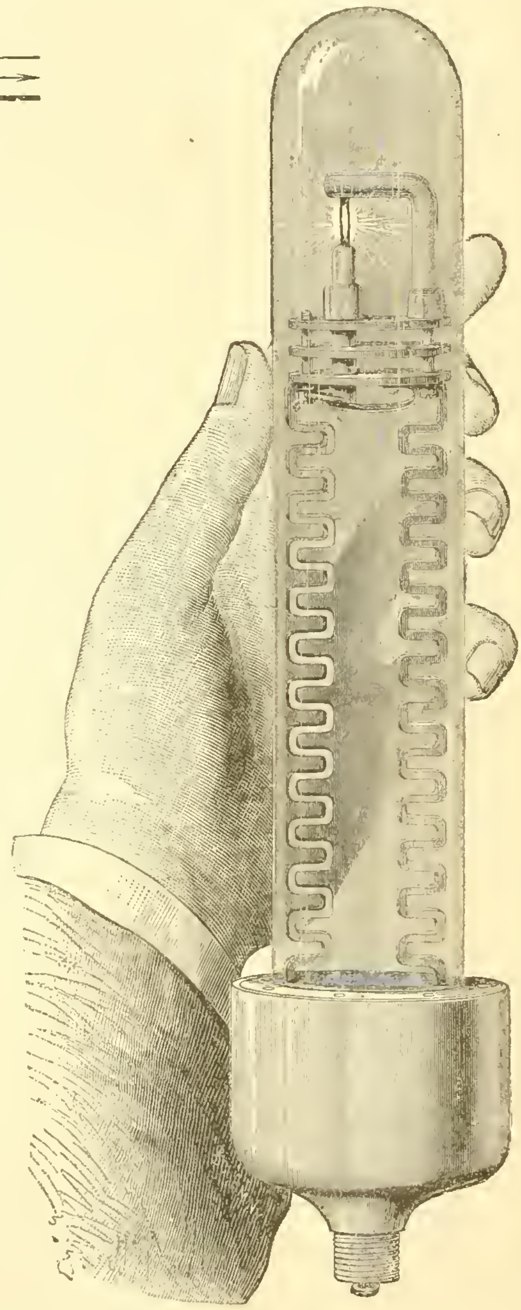
1191



1192.



1193.



Kohn of St. Petersburg devised a material improvement on this lamp in 1875, the important feature of which consists in the use of a number of carbons placed vertically between platforms, and having stems of unequal heights extending above the upper platform. All are inclosed in an exhausted glass vessel. Above the stems, and resting of course on the highest, is a swinging lid through which the current passes to the carbon touched. As this carbon gradually consumes it becomes thinner, and finally breaks. The lid then drops down on the next highest stem, and a second carbon is rendered incandescent. This goes on until all the carbons are consumed, when the lid falls upon a copper rod, and, although the lamp is extinguished, the current passes on through it to another lamp. Each carbon lasts about two hours. The light is mild and agreeable, but is much more costly than that of gas. Its intensity is about equal to 20 Carcel burners.

*Fontaine's Lamp.*—M. Fontaine has devised a lamp which is represented in Fig. 1192. The essential features are as follows: The carbons are encased at each extremity in rigid contacts, and are held firmly so that the lamp operates in any position. The current passes automatically from one carbon to the other through the action of an electro-magnet placed in the circuit.

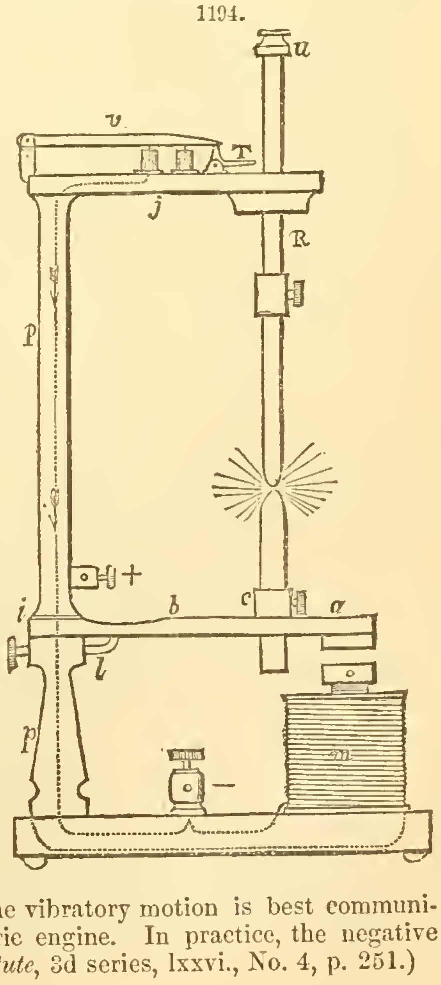
*The Sawyer-Man Lamp*, represented in Fig. 1193, has a slender pencil of carbon placed as shown. The light-giving apparatus is separated from the lower part of the lamp by three diaphragms, to shut off downward heat radiation. The copper standards lower down are so shaped as to have great radiating surface, so that the conduction of heat downward to the mechanism of the base is wholly prevented. The electric current enters from below, follows the line of metallic conduction to the "burner," thence downward on the other side, connecting with the return circuit. The light-producing portion is, of course, completely insulated, and also sealed at the base, gas-tight. The glass vessel is charged with pure nitrogen, and the crumbling of the carbon due to sudden heating when the lamp is lighted is claimed to be prevented by the use of a switch so constructed that it is impossible to turn the current on or off suddenly. A detailed description of this apparatus will be found in the *Scientific American*, xxxix., 351.

*The Jablochkoff Kaolin Light.*—M. Jablochkoff, the inventor of the electric candle already described, has obtained excellent results from incandescent kaolin, through the medium of which, by employing a number of separate secondary coils, one to each candle, for one primary, the current can be simply and effectively divided. The passage of the current through the kaolin makes the circuit complete, and a number of lights can be joined up in the same circuit, so as to form a set of luminous centres. MM. Denayrouze and Jablochkoff have easily obtained 50 luminous centres of various intensity in graduated series, the weakest yielding a glow equivalent to one or two gas-burners, the strongest equal to 15 burners, from one current. By employing a magneto-electric machine giving alternating currents, the current interrupter and condenser of the induction coil may be dispensed with, the alternating currents being simply passed through the primary coil. Again, by employing a magneto-electric machine yielding several powerful intermittent currents, the induction coil with its several secondary coils may be dispensed with altogether, and the magneto-electric currents passed through the candles. The lights require to be shaded by ground or opal glass shades to diffuse the rays. The consumption of kaolin is very small, a piece the length of a centimetre lasting 10 hours.

III. The Geissler-Tube Light.

The attempts to use the stratified light which is yielded by the electric discharge in passing through Geissler tubes containing various gases have not been attended with advantageous results. In 1865 M. Gervais devised an apparatus in which 2 bichromate-of-potash elements transmitted a current to an induction coil, and from the latter the flow traversed a tube charged with carbonic acid. The apparatus was compactly arranged, and yielded a mild, pleasant light, which was easily maintained for several hours under water; but the general conclusions to be deduced from the experiments indicate that the illumination was of too feeble a nature to admit of any extended practical utilization.

1194.




IV. The Electric-Spark Light.

When an electrical current which flows through a conductor of considerable length is suddenly broken, a bright flash, called the extra spark, appears at the point of separation. The extra spark will appear, although the current is not sufficient to sustain an arc of any appreciable length at the point of separation. In order to obtain a continuous light from this spark, Professors Thomson and Houston of Philadelphia have devised an apparatus in which one or both of the electrodes, which may be the ordinary carbon electrodes, are caused to vibrate to and from each other, so that in their motion toward each other they touch, and afterward recede a distance part which can be regulated. These motions or vibrations are made to follow one another at such a rate that the effect of the light produced is continuous; for, as is well known, when flashes of light follow one another at a rate greater than 25 to 30 per second, the effect produced is that of a continuous light. The vibratory motion is best communicated to the electrodes by an automatic vibrator or an electric engine. In practice, the negative electrode only is vibrated. (See *Journal of the Franklin Institute*, 3d series, lxxvi., No. 4, p. 251.)

Fig. 1194 represents the construction of this apparatus. A flexible bar of metal $b$ (the extent of whose vibrations is regulated by the adjustment of the rigid bar $l$) is attached at one end to the pillar $pp$, and carries at its other end an iron armature $a$ placed opposite the adjustable pole-piece of the electro-magnet $m$. The negative electrode is supported in a collar $c$, and the positive one in the arm $j$. The pillar $pp$ is divided into two insulated sections at $i$; the upper section conveys the current from the binding-post marked + to the arm $j$ and the rod $R$, supporting the positive electrode. The magnet $m$ is placed, as shown by the dotted lines, in the circuit which produces the light. The pillar $pp$ is hollow, and has an insulated conducting wire inclosed, which connects the circuit-closer $v$ to the binding-post marked —. The current is conveyed to the negative electrode through $b$ and the coils of the magnet $m$. When the electrodes are in contact, the current circulating through $m$ renders it magnetic and attracts the armature $a$, thus separating the electrodes, when on the weakening of the current the elasticity of the rod $b$ again restores the contact. During the movement of the negative electrode, since it is caused to occur many times per second, the positive electrode, though partially free to fall, cannot follow the rapid motions of the negative electrode, and therefore does not rest in permanent contact with it. The slow fall of the positive electrode may be insured either by properly proportioning its weight or by partly counterpoising it, so that it thus becomes self-feeding. Various modifications of this lamp have been devised by the Messrs. Siemens.

Applications of the Electric Light.

*Industrial Illumination.*—The electric light is especially well adapted for the illumination of workshops and large buildings. It is the only light by which fine work can be carried on by night as well as by day, and its abundance is such that it becomes diffused in manner similar to daylight, so that it is only when especially precise work is being executed that a second lamp is needed to illuminate the shadows cast by the first. The light is not fatiguing to the eyes, and it possesses the great advantage of exhibiting colors in their natural hues, so that it may be used in dye-works, stores, etc. As a general rule, one lamp (carbon points) will illuminate 5,120 square feet in a machine shop, half that space in a weaving-room, spinning-loft, or printing-office, and four times the space in a shipyard, court, quay, or the open air. Improvements in the electric light tend constantly toward rendering its working more economical. The principal results of experience up to the date of issue of this work will be found in M. Fontaine's "Electric Lighting" (1878).

*Lighthouses.—The Souter Point Light.*—The great electric light at Souter Point, England, is located 3 miles below the mouth of the river Tyne. Its condensed beam is equal in power to 800,000 candles. Two rotary magneto-electric machines of the Holmes pattern are driven by two 3-horse-power engines. Each machine consists of 8 radial frames, to each of which are attached 36 magnets, making 288 in all, and the poles are alternately pointed toward and from the axis of the machine. The number of revolutions made by each machine per minute is 400, and as 16 sparks are produced by each magnet at each revolution, the number of sparks at the carbon points of the lamp is 6,400 per minute when one machine only is in operation, as is the case in fair weather, and 12,800 per minute when both machines are at work. The electric lamp consists of two carbon points, each about 10 inches long by half an inch square in section, placed end to end in a vertical position. The rate of feed is one inch per hour each. An oil-lamp is placed under the electric lamp, and is always filled and ready to be substituted in case of accident to the latter or to the machinery.

Fig. 1195 illustrates the disposition of the different parts of the lenticular apparatus. $A$ is the focus at the meeting-point of the carbon pencils; $b$, the holophote; $C$, the upper totally reflecting prisms; $D$, the fixed dioptric apparatus; $E$, the revolving frame of flash-panels; $W$, revolving gearing; $T$, the burner of the oil-lamp; $I$, telescopic tubes for the supply of oil and the overflow, for use if the oil-lamp should be substituted at any time for the electric lamp; $F$, the oil-reservoir; $M$, the oil-supply pipe; $J$, cylindrical shaft for transmission of the beam of reflected light to the lower light-room; $O$, the lower reflecting prisms; and $P$, the window of the lower light-room. The tower is 150 feet in height, and the light, which revolves every half minute, is visible for 20 miles.

*The South Foreland Lights.*—The great electric lights at South Foreland, two in number, are 3 miles east of Dover Pier, on the high chalk cliffs overlooking the Strait of Dover. They are about 1,000 feet apart, the high light 372 and the low one 275 feet above the sea, and form a range or lead as a guide to clear Goodwin Sands, one of the greatest dangers in British waters. The magneto-electric machines used to generate the current are of the Alliance pattern. (See Dynamo-electric Machines.) Each machine is composed of 96 helices mounted upon 6 gun-metal wheels, each having 16 helices. Between these wheels are placed the magnets, 8 in each division, 40 of which are composed of 6 layers riveted together, and 16 (the end ones) similarly constructed, but having only 3 leaves or layers. These magnets, which are mounted in frames, are stationary, while the helices revolve at the rate of 400 revolutions per minute. (For details of tests of this and other machines, see Dynamo-electric Machines.) Each electric lamp contains two carbon rods, 10 inches long by three-eighths of an inch square. The rods are made from coke-dust, and the rate of consumption is 34 inches per night for each light. The lenses are of about the same size as ordinary third-order lenses, 39 inches interior diameter. (See Lighthouses.) With the machine above described the power of the condensed beam from each light is estimated at 180,000 candles. The lights are fixed.

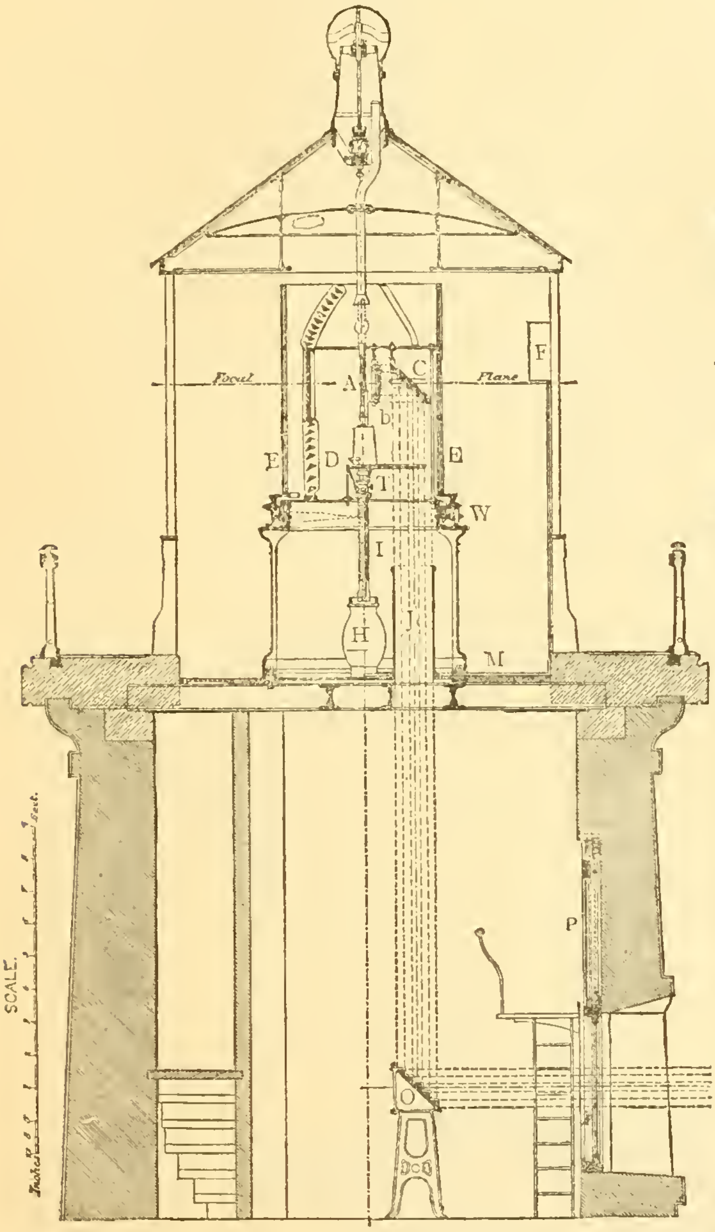
Two large and important electric lights have also been established on the headland known as the Lizard, on the south coast of England.

For full details concerning the electric lights on Cape La Hève and elsewhere on the French coast, reference may be had to "European Lighthouse Systems," a report by Major George H. Eliot, U. S. A. (New York, 1875).

*Vessels' Sea Lights.*—The electric light has been adapted to sea-going vessels, and has proved a valuable method of indicating the positions of the latter, and so reducing the dangers of collision. On board of war vessels it is a potent safeguard against the approach of small torpedo craft under

cover of the night. The arrangement of the light for marine purposes, as devised by MM. Sautter and Lemonnier, is represented in Fig. 1196. The voltaic arc is obtained from a Serrin lamp, the beam of which is concentrated by a Fresnel lens 0.6 metre in diameter, and composed of 3 dioptric and 3 catadioptric elements. (See LIGHTHOUSES.) The lamp and lens are carried on a cast-iron drum, which is movable around a vertical axis, and capable of oscillating about its horizontal axis without changing the relative positions of lens and lamp. By this means the luminous beam may be pro-

1195.

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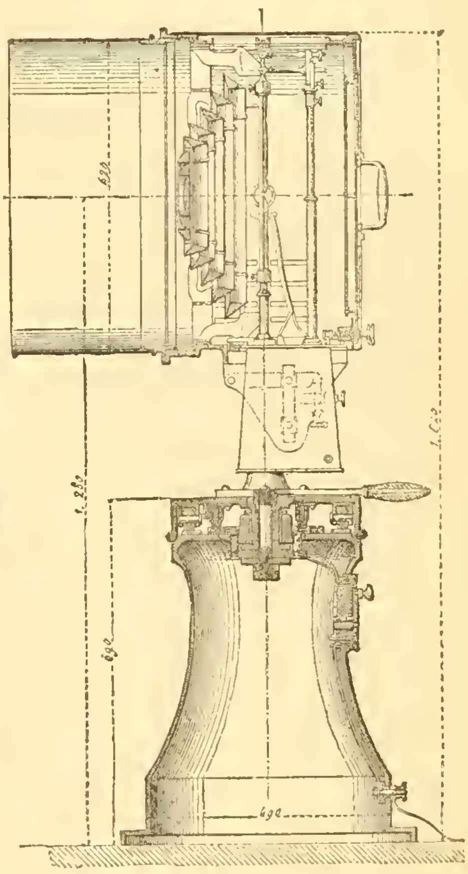


jected at will in any direction by the operator, who, stationed in rear of the apparatus, manages suitable handles. A small lens is so disposed as to project, on a screen of ground glass in rear of the apparatus, the image of the carbons, so that the rate of consumption of these may be constantly watched. Means are provided for varying the position of the lamps so as to cause the beam to diverge more or less. The apparatus is fixed on a cast-iron pedestal on the ship's bridge or deck. As arranged on board the Amérique, a steamer of the Compagnie Générale Transatlantique, the lamp is placed on a tower elevated about 16 feet above the deck. The lantern is of prismatic glass, and illumines an arc of 225°, so that the vessel herself is left completely in the shade. The luminous beam is about 31 inches in diameter. The lamp is supplied by a Gramme machine of 200 Carcel-burner power, driven by a 3-cylinder Brotherhood engine. This light is, by an ingenious automatic arrangement, made intermittent, so as more quickly to attract attention. It is visible at a distance of about 10 marine miles to an observer situated 19 feet above the water.

ELECTRIC LOOM. This extremely ingenious contrivance, in which the usual Jacquard cards are replaced by an electrical arrangement worked by a pattern prepared in tin foil with insulating varnish, is the invention of Cavaliere G. Bonelli of Turin. A simple metal plate, perforated with holes, each of which is provided with a kind of piston, successively plays the part of each successive paper card in the usual arrangement. The pistons fill up every hole that is not required, but are withdrawn by electro-magnets from those holes which require at each beat of the loom to be kept open. This is effected as follows: A sort of metal comb, each tooth of which is the terminal of a separate insulated conducting-wire, rests on the prepared pattern. Whenever a tooth touches the tin foil, a circuit

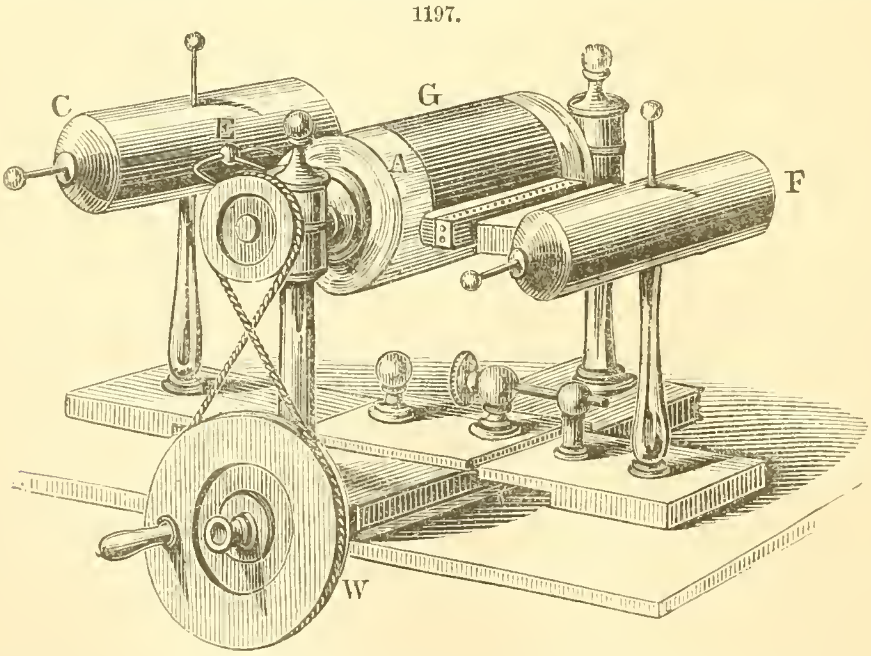
is completed through its conducting-wire; but when a tooth rests on the varnish, the circuit is broken. Each conducting-wire includes in its circuit an electro-magnet. The pistons already spoken of are each composed of a small iron shank and brass button-shaped head, and are all held horizontally in a frame, one opposite each electro-magnet. In one position of this frame, the heads of the pistons project through the openings of the metal card or perforated plate; the diameter of each hole is a little larger than the head of the corresponding piston, each piston being exactly in the centre of its corresponding hole. In this same position all the soft-iron shanks touch the poles of the corresponding magnets, and the metal comb rests on the prepared pattern. A certain number of the magnets corresponding to the uncovered portions of the tin foil are therefore active or attract the shanks, but the others exert no attraction. The frame with the pistons is now pulled forward away from the magnets: those pistons which are opposite the active magnets are held back, sliding in their frame, so that the button-heads pass behind the perforated plate; but the other portions come forward with the frame, leaving the magnets. The perforated plate then drops a little way, and by this simple contrivance all those piston-heads that were in front of the plate are retained there, whatever pressure comes against them, for they are now eccentric from the holes. The plate in this condition presents a perfect analogy with the common prepared card: a certain number of holes corresponding to the metallic part of the pattern are vacant; the rest of the holes are blocked up and present an unbroken surface, by which the proper hooks of the Jacquard loom (see Looms) are acted on during one stroke. The perforated plate is then brought back to the position first described, the prepared pattern is moved on a little step, and the same process is repeated. When shuttles with several different colors are to be used, the pattern is subdivided into insulated portions corresponding to the separate colors by removing a very thin outline of foil around each; all the parts corresponding to one color are afterward connected. As each shuttle is thrown, the battery is brought in contact with the appropriate series of insulated patches of tin foil, producing a succession of different cards, and the pattern is not shifted forward until all the colors are exhausted. After the completion of each fresh combination on the perforated plate, the battery circuit is broken by a proper contact-breaker, and the injurious spark is thus avoided, which would otherwise occur when the comb is lifted from the pattern prior to a shift.

ELECTRIC MACHINES (STATIC). Electrical phenomena are usually and conveniently divided into two chief classes: the first comprising those which depend upon the mutual action of bodies while they are in different electrical conditions; and the second including those which accompany the process of electrical equalization. Phenomena of the former class, since they depend on the existence of a particular electrical *state* in the bodies which produce them, are called electro-statical; while those of the latter class, which depend upon the occurrence of an electrical *process* requiring the expenditure of energy in some shape or other in order that it may go on continually, are called electro-dynamical.

The first condition for the production of any electro-statical phenomenon is the means of developing the electrical state. Instruments for this purpose are commonly called electric or electrical machines. These act either by friction or by electrical induction.

I. Frictional Machines.—This type of apparatus was first constructed to be operated by the successive approximations or contacts of the parts of the revolving glass cylinder *A*, Fig. 1197, against the parts of a rubber attached to a hollow metallic cylinder *F*, mounted on a pillar of glass. This

1197.




pillar is sustained on a sliding base-board at the bottom, capable of being moved by a screw toward the glass cylinder, to regulate the intensity of the pressure, and consequently of the friction of the rubber. The rubber is made of leather stuffed with horse-hair to constitute an elastic cushion.

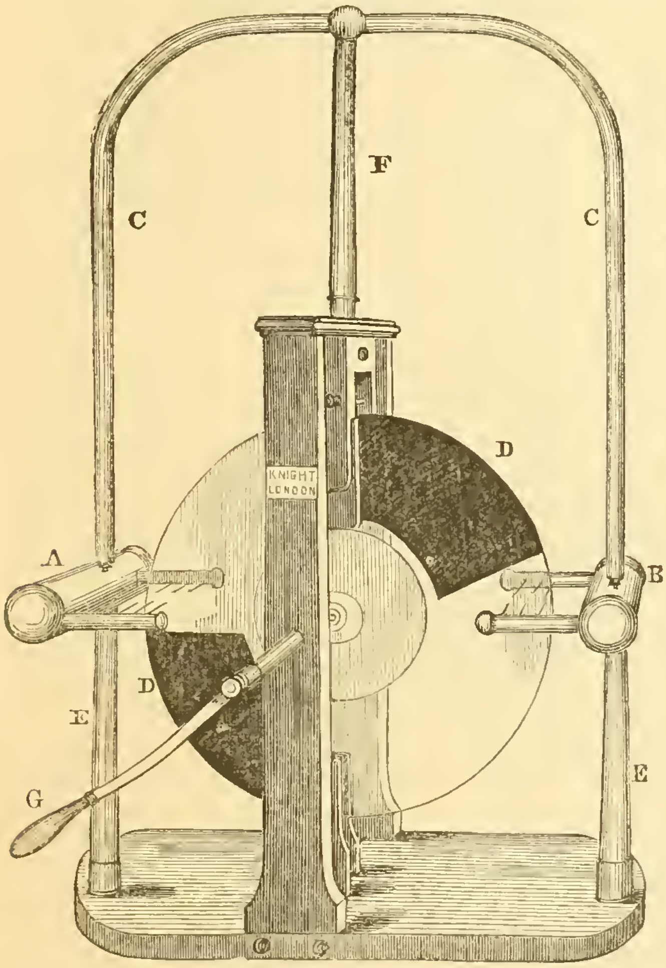
Another hollow metallic cylinder, termed a "prime conductor," is represented at *E*, furnished with a row of pointed wires facing the glass cylinder, designed to serve for collecting the electricity excited therefrom. To prevent the escape or propagation of the electro-dynamic action from the prime con-

ductor, it is *insulated* by the intervention of a non-conducting glass pillar. A flap of silk, $G$, is attached to the cushion, and is spread out over the top of the revolving cylinder, to suppress the dissipation of the electric action by the reaction of the air, before it reaches the row of points at $E$.

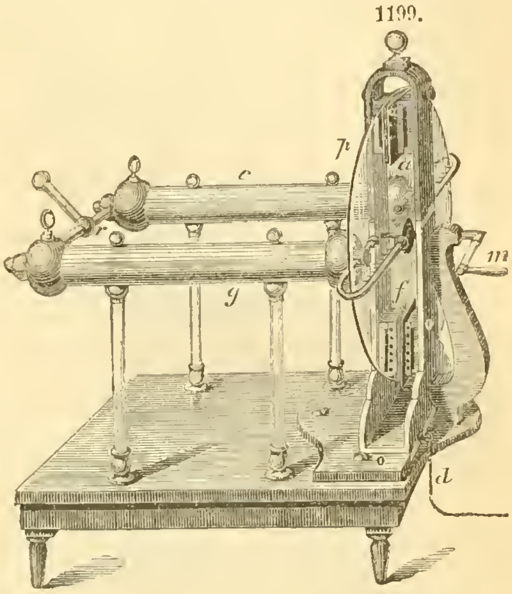
A revolving movement may be imparted to the glass cylinder by the animal motive power of the human hand applied to turn the crank-handle attached to the pulley $W$. Into this pulley a grooved score is turned, adapted to receive the cord that extends from it to a similar groove in a pulley attached to the axis of the glass cylinder.

The conductor $E$ has also been denominated the "positive" conductor, in contradistinction to the conductor attached to the rubber, which is denominated the "negative" conductor, the former being supposed to contain an accumulation or "positive" excess of the fluid, and the latter to have yielded

1198.




1199.




up a portion of its natural share of electricity, and to be reduced to a "negative" state.

To augment the excitation, it is usual to apply to the rubbing surface of the cushion a compound of metals triturated with lard. One part by weight of tin and two parts of zinc are melted together, and mixed with six parts of mercury, which are to be well stirred together until solidified. The brittle compound is then pulverized in a mortar, and mixed with a sufficient quantity of lard to reduce it to the consistence of a paste.

Fig. 1198 represents a simple form of plate machine. The glass plate $D\ D$ is caused to revolve by means of the crank $G$. Attached to the inner sides of the supporting pillars are four cushions compressing the plate between them at the upper and lower portions of the disk, each having flaps of silk appended thereto. The intensity of the pressure of the cushions is regulated by screws. The two opposite conductors $A\ B$ are supported by two stout glass pillars $E\ E$, fixed at each end of the mahogany base-board on which the other parts of the machine are mounted. The brass arch $C\ C$ is sustained at the centre and lower ends by the glass pillars $F\ E\ E$, and connects the two conductors $A\ B$.

*Ramsden's Machine*, a more modern form of this apparatus, is represented in Fig. 1199. Between the two supports in which the glass plate turns are two pairs of cushions of leather, stuffed with hair and covered with some amalgam mixed with grease. Two large hollow cylinders of brass $c$, with globular ends, each supported by two glass pillars, constitute the reservoir for receiving the electricity, which in this case is positive. They are called prime conductors, and are supplied with U-shaped rods of metal furnished with points along their sides, called combs, for the purpose of receiving the electricity from the glass plate, the arms of the U being held upon the other side. The other ends of the conductors are connected by a rod $r$, from the middle of which projects another short rod terminating in a knob for delivering the spark.

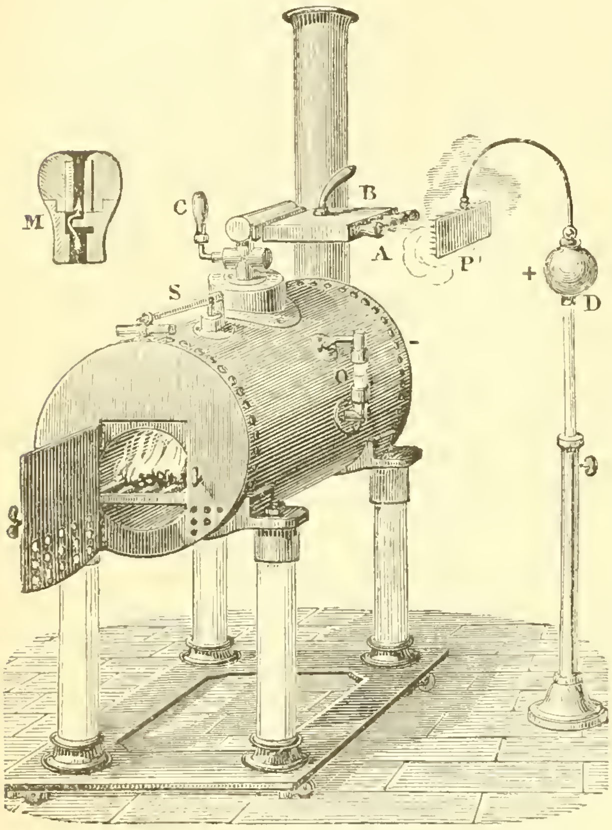
Nairne's machine is constructed similarly to that represented in Fig. 1197, having a cylinder and silk rubber. Van Marum's machine has two glass plates nearly $5\frac{1}{2}$ feet in diameter, separated by about 8 inches, and pressed by 8 pairs of rubbers. With this apparatus sparks 24 inches in length have been obtained.

*Armstrong's Hydro-electric Machine*, Fig. 1200, also belongs to this class. It consists of a small wrought-iron plate boiler standing on glass legs. A stop-cock $C$, when opened, allows the steam to pass through a number of tubes in the box $B$, containing cold water for cooling the steam. The ends of the tubes are furnished with jets whose construction is such as to increase the friction, and the jets are lined with hard wood, as shown in the figure at $M$. The metal plate $P$, armed with

points, collects the electricity, which is ordinarily positive, and conveys it to the prime conductor *D*. Faraday showed that the generation of electricity in this machine is caused by the friction of minute globules of water passing through the jets.

The mechanical *pressure* of bodies, as well as friction and contact, propagates electrical action. Elastic India-rubber or caoutchouc develops extraordinary electric excitation by sudden compression. Sparks issue in vivid coruscations to a distance of several inches from between the rollers used for compressing sheets of this material in the process of incorporating it into manufactures of cloth. In certain processes of calico-printing, the India-rubber, dissolved in spirits of turpentine and alcohol, and mixed with ultramarine blue or other colored substances, is passed with great pressure between the engraved copper rollers and the cloth to be imprinted therewith. A torrent of sparks is noticed to issue from the compressed India-rubber, too intense to be sustained by the knuckles, held near them, without absolute pain. Indeed, the process of printing with this material was finally suspended from the danger of burning up the building and machinery employed, the sparks having actually set fire to the composition of turpentine, alcohol, and India-rubber, and caused the cloth in the machine to be burnt up.

1200.




II. Machines acting by Electrical Induction.—An insulated conductor charged with either kind of electricity acts on bodies in a natural state placed near it in a manner analogous to the action of a magnet on soft iron; that is, it decomposes a supposed neutral fluid, attracting the opposite and repelling the like kind of electricity. The action thus exerted is said to take place by influence or induction. Thus, if a positively electrified body A is brought into the neighborhood of two insulated (and previously unelectrified) conductors, B and C, each of these becomes positively electrified, in the sense of tending to impart positive electricity to other bodies, as long as A is present; if, however, B is nearer to A than C is, B becomes more strongly positive than C, or the tendency of B to give positive electricity to C is greater than the tendency of C to give positive electricity to B. Consequently, if B and C touch each other, electricity flows from B to C to an extent depending on the difference between the electrifications of the two bodies, and electrical equilibrium is established between them. If now they are separated from each other, and removed beyond the range of the sensible influence of the body A, they are both found to be electrified, B negatively and C positively, while A remains exactly in the same condition as at first, and therefore capable of producing the same effects upon B and C, or upon other conductors which may be substituted for them, any number of times. The ultimate electrification of the conductor B is greatest when the conductor C with which it is put into communication, while under the influence of A, is the earth.

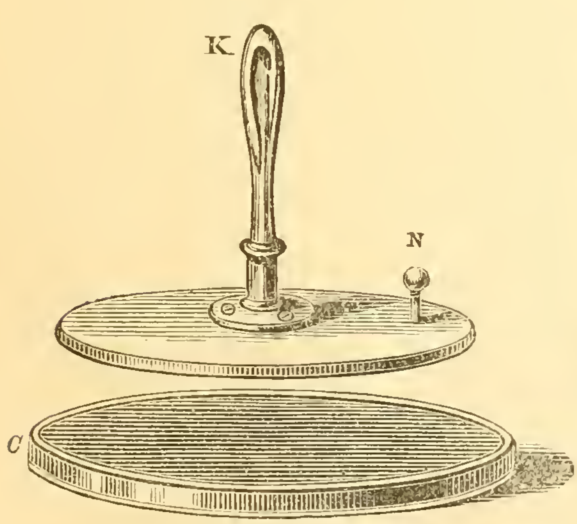
By proper arrangements the conductor B, which in the manner indicated above can be repeatedly electrified in the opposite way to the body A, can be made at each time to impart its electrification to another insulated conductor A′, thus electrifying it more and more strongly. By then causing the conductor A′ to act in its turn upon B, B will be electrified in the opposite way to A′, or similarly to the body A. If B when thus electrified is made to give up its electrification to A, this will become more strongly electrified. Thus by letting A and A′ act alternately upon B, and each time making this give up to A′ or to A respectively the electricity it has received while under the action of the other, each of these bodies can be electrified to a greater and greater degree, and will therefore act with greater and greater intensity upon the conductor B, and the other conductor, whatever it may be, with which B is at each operation put into communication. This, in general terms, is the principle upon which the most improved forms of electrical machines act.

*The Electrophorus* of Volta, Fig. 1201, is a familiar example of the practical application of the foregoing principle. It often consists of a cake of sealing-wax, which material is selected as being a readily excitable substance. A more tough and useful compound is commonly used, made by melting together equal parts of pitch and rosin, combined with a little linseed oil. This composition, while in a melted state, is poured into a flat circular tin dish, having a rim of about half an inch in height, as shown at *C*. A round metallic plate, adapted to the size of this cake of resinous matter, is affixed to the insulating glass handle *K*, by which the plate of metal may be alternately lifted from the cake of resin, and again brought into contact therewith. Whenever it is desirable artificially to propagate the electric action from the cake of resin to some adjacent body, the circular plate of metal is taken by the tip of the glass handle, and brought into contact with the cake of resin, and at the same time the finger is brought to touch the plate. Then the finger is to be withdrawn, and the plate removed by holding the tip of the glass handle. The electrophorus is used practically for producing instantaneous light, by causing an electric spark, always excitable in an instant from the plate

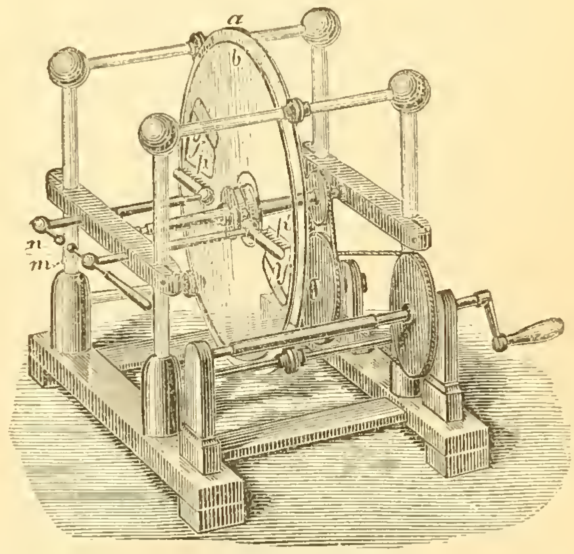
on being lifted from the cake of resin, to kindle a jet of hydrogen gas artificially arranged to issue from a small apparatus, containing a lump of zinc in acidulated water.

*The Holtz Electrical Machine*, Fig. 1202, is remarkable for its great power. A circular plate *a* is fixed in an insulating frame. In opposite sides, near the circumference, are two large orifices, which are partly covered at the back by two bands of thick paper *f f'*, having points projecting in the opposite direction to that of the motion of a second glass plate *b*, somewhat smaller than *a*, and made to revolve very near it. Opposite the face of the movable plate, which has no orifices, there are metal combs *p p'*, connected with insulated conductors which terminate in adjustable knobs, *m* and *n*. An orifice in the centre of the fixed plate gives passage to the axis of the movable one, which can be rapidly rotated by a system of hand-wheels. The machine is started by bringing the knobs *m* and *n* of the conductors together, and electrifying one of the armatures, say *f*, by holding against it a plate of ebonite which has been negatively excited. After a few turns of the plate both armatures become highly charged with opposite kinds of electricity, *f'* becoming positive; and if the knobs are separated a stream of sparks will pass from one to the other. By increasing, within a certain limit, the distance between the knobs, the sparks become larger and less frequent; but beyond this limit, which depends upon the insulation and working order of the machine, the sparks will no longer pass, and unless the knobs are quickly brought together the machine will cease to act. The following is a brief explanation of its action: The negative electricity of the first armature tends to repel the same fluid in its vicinity, and to attract the opposite; consequently negative electricity flows from the face of the movable plate to the points of the comb, while positive electricity is discharged by the comb upon the plate. This will cause the comb of the second conductor, which at the commencement, as has been said, is in connection with the first, to become negative, while each portion of the glass plate will pass from the first to the second comb positively electrified. When successive portions of the plate thus charged arrive opposite the second armature, the latter, through its point, discharges negative electricity upon the plate and receives positive in return, thus becoming positively charged. Positive electricity from the face of the plate also passes to the second comb, and the latter discharges negative electricity upon the plate, which then passes on to the first armature and comb negatively electrified. Therefore the comb will discharge positive electricity on and receive negative from the plate, and the armature will also receive a higher negative charge from the other side of the plate, because the latter is charged with higher tension. The effect is to cause the plate to leave the first comb more highly positive than it was the first time, and on again coming opposite the second armature to increase its positive charge. Both armatures become thus in a short time highly charged with opposite electricities, the tension of which is only limited by the degree of insulation. A strong current of positive electricity, it will therefore be seen, is constantly passing through the conductors from the second to the first comb, and a corresponding current of negative electricity from the first to the second comb; and when the knobs of the conductors are separated the electricity will leap from one to the other. It is moreover evident that the action of the machine requires that each part of the movable plate be charged with electricity of an opposite kind to that of the armature it leaves, and of the same kind to that of the one

1201.



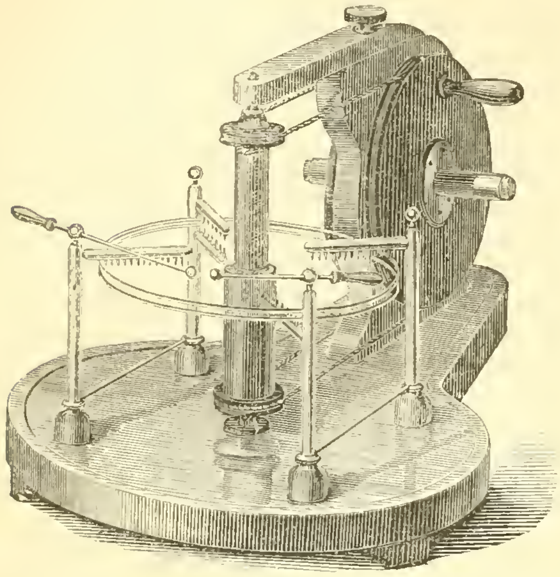

1202.



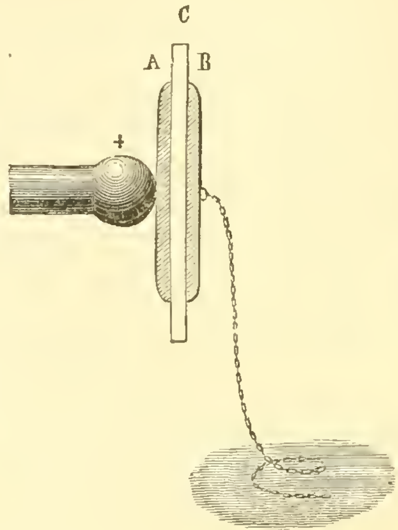

it approaches. This condition, however, cannot continue if the conductors are so far separated as to prevent communication, or are beyond striking distance, because there would then simply be two armatures in opposite electrical conditions, with a moving plate passing from one to the other and gradually equalizing the charge. The inventor has modified this machine by placing the plates horizontally and turning them in opposite directions, as represented in Fig. 1203. Neither plate has openings, but two combs are placed above the upper plate opposite each other, and two others below the lower plate, at right angles to the upper ones. Each of the upper conductors is connected with one of the lower, so that there are only two conductors. The machine is started by holding for a short time an excited plate of ebonite opposite one of the combs. Sometimes, as in the figure, a third upper comb is placed above one of the lower combs, which appears to increase the power. In both forms of the machine work is expended in turning the plates in opposition to electrical attrac-

tions and repulsions, by which mechanical is converted into electrical energy. It will always be found difficult to obtain good results with electrical machines in damp weather. By warming the glass insulators, however, and frequently rubbing them with a warm dry cloth, their non-conducting

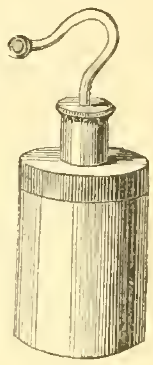
1203.



1204.



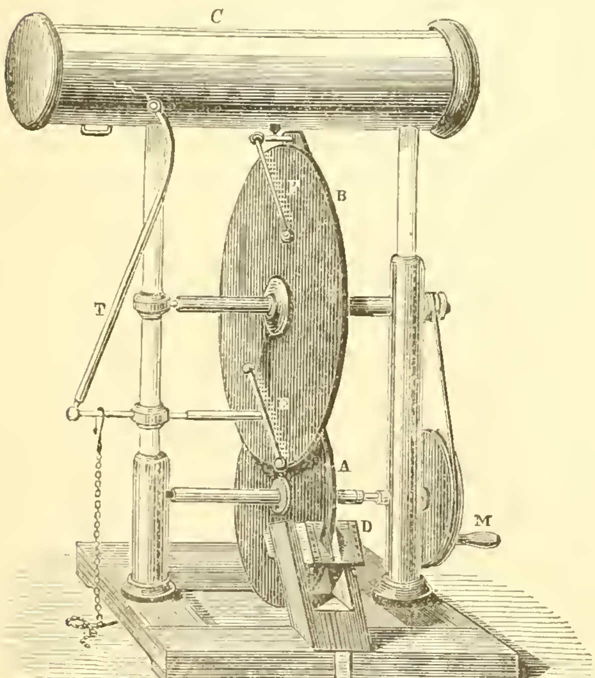

1205.



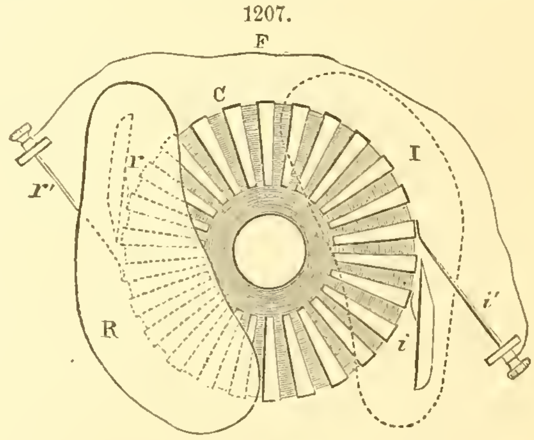
property may be in a degree preserved. The Holtz machine is more sensitive to moisture than the ordinary kinds.

*Electric Condensers or Accumulators for Statical Electricity* are instruments by which through the agency of induction we are enabled by means of a second conductor to augment the quantity of electricity capable of being stored up on the surface of the first, an insulated conductor. Every condenser consists of two conductors separated by an insulator, or *dielectric*. The one conductor must be insulated, the other in connection with the earth or some very large neutral body. The usual form of condenser is made by separating two conductors by a plate of glass, as shown in Fig. 1204. When either posi-

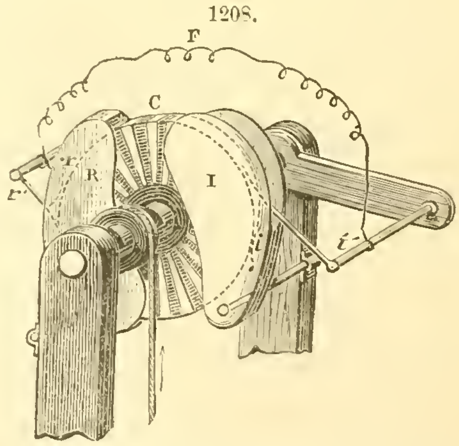
1206.




1207.




1208.




tive or negative electricity exists uncombined with its opposite kind of electricity, and is capable of exerting to a marked and obvious degree its attractive and repulsive powers indifferently on surrounding bodies, it is said to be "free." When either kind of electricity exists uncombined with its opposite kind, but is incapable of attracting or repelling or manifesting its inductive power on bodies in general, in consequence of the special inductive action of an adjacent store of the opposite electricity acting

through the medium of a dielectric, it is said to be bound, captive, disguised, dissimulated, or latent (Angell). The quantity of electricity which can be stored up on the surface of the plates of a condenser is limited: 1, by the tension of the electricity of the prime conductor; 2, by the distance between the two plates, or in other words by the thickness of the intervening dielectric; 3, by the cohesive power of the dielectric; 4, by the specific inductive capacity of the dielectric used.

*The Leyden Jar*, Fig. 1205, is the most convenient and portable form of electric accumulator or condenser. It consists of a glass jar of suitable thickness, covered inside and out with a coating of tin foil reaching to within 2 to 4 inches of the top of the jar. A varnished wooden cap fits into the neck of the vessel, and supports a brass knob, wire, and chain terminating below in contact with the tin-foil coating at the bottom of the inside of the jar. A Leyden battery consists of a series of Leyden jars, usually placed in a box or tray, the bottom of which is lined with tin foil, which thus electrically unites the exterior coatings, their interior coatings being united by means of brass rods connecting the knobs of the jars.

*The Carré Machine.*—In this apparatus, Fig. 1206, a disk *A*, of ebonite or glass, passes between two leather cushions *D*, and is carried directly on the axle of the crank *M*. A pulley on the same shaft communicates, by means of a cord, rapid rotation to another and larger ebonite disk *B*. In face of the latter are two combs, *E* and *F*, the second of which is opposed to a fixed leaf of ebonite furnished with paper layers, terminating in points and designed to serve as a second inducer, as in the Holtz machine. The upper comb communicates with an insulated conductor *C*, and the lower comb is also insulated, or communicates with the soil. An arm *T* serves as exciter.

*The Thomson Machine*, Figs. 1207 and 1208, is known as the charge-reproducer. A wheel *C*, of ebonite, carries a certain number of insulated metallic plates, disposed in sectors on the two faces, and appearing at the circumference like the teeth of a gear-wheel. Two metallic plates, *I* and *R*, bent so as to envelop completely half of the wheel (one of these is indicated by dotted lines), serve both as inducer and receiver; that is to say, they act by induction on an intermediary conductor *F*, and then receive by the effect of the motion the electricity so developed. Hence it results that the charge of each of them augments at first in geometrical progression, as in all analogous apparatus. Two receiving springs, *i* and *r*, communicating separately with the metallic envelopes in the interior of which they are placed, receive the electricity carried by the different sectors and communicate it to the corresponding envelopes. Two other springs, $i'$ and $r'$, called conductors, placed behind the former ones with reference to the direction of rotation of the wheel, are connected by the wire *F*. Suppose that one of the inducers, *I*, for example, is first charged with negative electricity. The corresponding spring, *i*, is then charged with positive electricity, which it communicates to the successive teeth of the wheel, which, by the receiving spring *r*, transmit this electricity to the second inducer *R*. The opposite spring, $r'$, is similarly charged with negative electricity, which comes back by the sectors and by the receiving spring $r'$ to the first inducer, *I*. As constructed, the wheel is not more than 2 inches in diameter, and may be set in motion by the motor of a Morse telegraph instrument. A few seconds after it is started it produces brilliant sparks. A dry pile of 40 elements, the two poles of which were placed in communication separately with the two conductors, sufficed to charge the machine or suddenly to reverse the electrical signs.

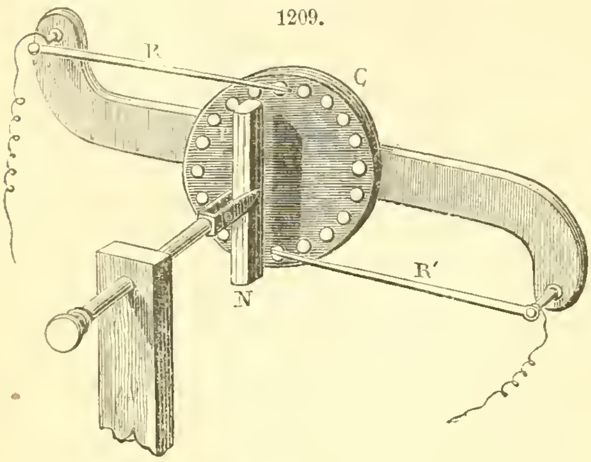
Thomson's tension equalizer, Fig. 1209, works like a series of contacts by a proof plane, in order to establish on a conductor the tension which exists in the surrounding atmosphere. A disk of ebonite *C*, turning around a vertical axis, carries a certain number of metal pins, on which are applied two springs *R* and $R'$, in communication with the two electrodes of an electrometer. If one of these springs is submitted to the influence of an electrified body, the keys which detach themselves from it in succession carry continuously electricity of contrary sign to that of the inducing body, until the electric density at the extremity of the spring becomes null. If the two springs are at the same time submitted to the influence of two conductors at different tensions, equilibrium will be attained at the end of a certain time, and quite rapidly, because the electricity carried off at one of the springs is taken to the other. The difference of tension of the two springs, or of the two electrodes of the electrometer, will be proportional to that of the two inducing bodies.

In Fig. 1210 is represented another Thomson machine, in which *T* is a metallic tube communicating with the soil. This is placed in the interior of a metal cylinder *I*, which may be termed the inducer, having negative tension. This tube is electrified positively; and if liquid drops are allowed to escape therefrom, they carry with them contrary electricity, which is reproduced indefinitely. These drops fall into another metal cylinder, *R*, the receiver, which has a funnel within. The electricity of the drops expands over the surface of the receiver, and the drops escape in a neutral state from the spout of the funnel. The charge of the receiver then augments more and more until sparks are produced between the cylinders, or until the drops no longer fall into the receiver, on account of their being thrown off laterally by the electric repulsion which they encounter. Under such conditions it is necessary to maintain the tension of the inducer *I* by a foreign source. But it will easily be seen that two similar apparatuses may be disposed so as to react one on the other, and to augment reciprocally their electric charges. For this purpose the receiver *R* (Fig. 1211) of the first communicates with the inducer $I'$ of the second, and the receiver $R'$ of the second with the inducer *I* of the first. The drops which fall from the second inducer $I'$ are then charged with negative electricity, which is collected in the receiver $R'$, which augments the charge of the first inducer *I*. Two conductors are united with the interior covering of two Leyden jars, *A* and *B*. These jars are covered exteriorly with tin, and contain a certain quantity of concentrated sulphuric acid. In the liquid are plunged leaden rods terminating below with leaden plates. The rods are surrounded with glass tubes, and pass through an ebonite cover, so that the absolutely dry air contained in the bottles is not affected by the atmosphere. If the glass (Glasgow flint) is of good quality, the insulation of the bottles may be so perfect that the electric loss may not exceed one one-hundredth of the charge in three or four days. Under these conditions, one of the jars being electrified at a tension so weak

as not to be appreciable but with a very delicate electrometer, the valves are opened in order to allow the water to escape drop by drop. These drops become subdivided into very small ones, which separate by their mutual repulsion. After a few minutes a rapid succession of sparks is produced in some part of the apparatus. It is stated that the loss of electricity in this apparatus is so small that a single drop falling from each tube every three minutes is sufficient to maintain the charge constant indefinitely.

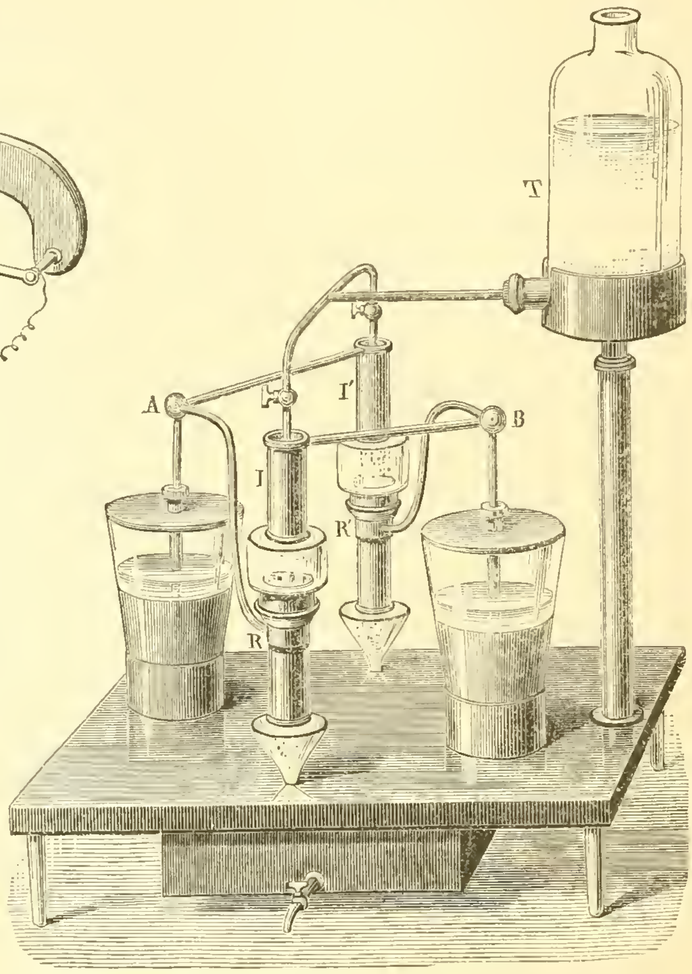
*The Inductorium.*—This is a device for producing induced currents by the action of another elec-

1209.



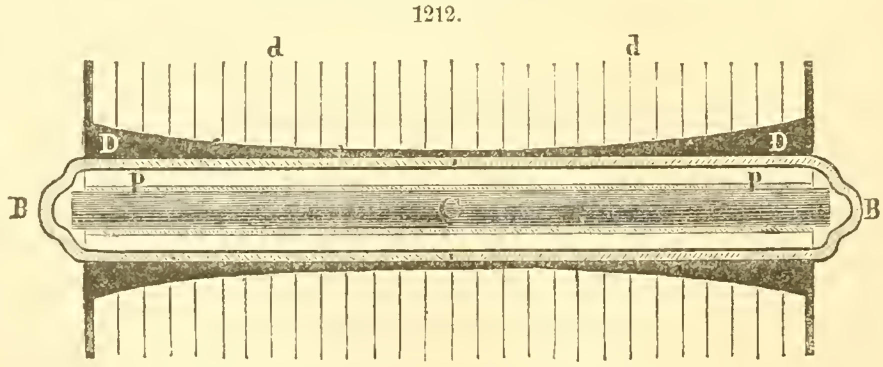

1210.


1211.




tric current, which is alternately opened and closed in rapid succession. All instruments of this kind consist essentially of a hollow cylinder, in which is a bar of soft iron or bundle of iron wires, with two helices coiled about it, one connected with the poles of a battery, the circuit of which is alternately opened and closed by a self-acting arrangement, and the other serving for the development of the induced current. By means of this apparatus, with a current from a few cells, physical, chemical, and physiological effects are produced, equal or superior to those obtainable with

1212.

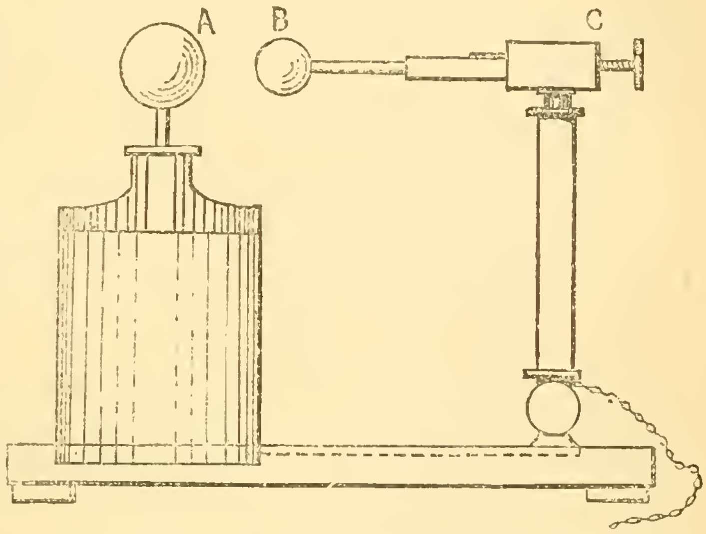



electrical machines, and even with the most powerful Leyden batteries. Fig. 1212 shows the internal construction of one of the large horizontal coils, arranged on Ritchie's plan. *C* is the core of soft-iron wires, separated by a thin layer of insulating material from the primary coil contained in the space *P P*. The two coils are separated by two heavy glass tubes *B B*, closed at the outer ends, while their open ends meet in the middle of the coil. *D D* is a hard-rubber bobbin, thinnest at its middle, and at *d d* are a number of thin insulating disks, which divide the bobbin into compartments which communicate with each other, so that the secondary wire is continuous from end to

end. One of the largest coils is that made for the Royal Polytechnic Institute, London. Its length is 9 feet 2 inches; diameter, 2 feet; weight, 15 cwt., including 477 lbs. of hard rubber. The core is 5 feet long and 4 inches in diameter, of No. 16 iron wire. The primary coil consists of 145 lbs. = 3,770 yards of No. 13 wire. The secondary coil consists of 150 miles of wire, weighing 606 lbs., and having a resistance of 33,560 ohms. The condenser is in 6 parts, each containing 125 square feet of tin foil, with 5 large Bunsen cells. The spark is 12 inches in length; and with 50 cells, it has been increased to 29 inches.

*Tests of Electric Machines.*—The usual method of testing electrical machines is by means of Lane's electrometer, Fig. 1213. This consists of a Leyden jar, the exterior armature of which communicates with a ball $B$, which by means of the micrometric screw $C$ may be adjusted as desired with reference to the ball $A$, which terminates the interior armature. If the ball $B$ communicates with earth and the ball $A$ with an electrical machine, a spark is produced between the two balls when the potential of the interior armature acquires a certain value. The electric energy which is exercised between two neighboring conductors and the electric densities on the opposite faces being proportional to the difference of the potentials, it is clear that the production of a spark between two conductors depends only on the difference of the potentials, and not on their absolute value, and that the quantity of electricity which escapes at each spark is always the same. The charge of the battery will then be exactly proportional to the number of sparks from the jar. The discharge, however, is not complete after each spark, because of residues; but if the experiment is continuously repeated, the total quantity of electricity that escapes is, as above stated, proportional to the number of sparks. The unit of measure—that is to say, the quantity of electricity expended at each spark—is proportional to the capacity of the jar, and depends on the explosive distance, which may be modified at will. It varies also with the resistance of the conductor which joins the exterior armature with the ball $B$.

1213.




In order to compare the yield of electricity of different machines, it is necessary to equalize the conditions under which they operate. The results given in the following table have been obtained with a Lane electrometer, the explosive distance of which was maintained at one millimetre, and all the machines were adjusted so as to give nearly similar yields. The quantity produced by the first Ramsden machine is taken as unity. The rubber being always larger than the comb (or any other conductor destined to collect the electricity), the useful surface of the electrified glass (plate or cylinder) may be considered as that which after being rubbed passes in front of the collector. In order to compare the surface utilized at each turn of the plate in the different models, it is necessary further to remark that if a machine has two pairs of rubbers, the faces of the glass are each rubbed twice, so that the surface of the annulus on the plate which corresponds to the length of the comb should be multiplied by 4. In the Nairne machine, on the contrary, the surface is rubbed but once. In Holtz and like machines, the two faces of the plate are counted, since one of the combs only serves as rubber and the other as collector.

*Table showing Results of Tests of Electric Machines.*

| NUMBER. | Machine. | Diameter. | Length of Comb. | Yield per Turn. | Utilized Surface. | Yield per Unit of Surface. |
|---|---|---|---|---|---|---|
| | | Metres. | Metres. | | Square metres. | |
| 1 | Ramsden, Fig. 1199 | 0.98 | 0.90 | 1 | 2.36 | 0.42 |
| 2 | Same, larger | 1.62 | 0.27 | 1.70 | 4.34 | 0.39 |
| 3 | Same, with collecting cylinders | 0.98 | 0.20 | 1 | 2.36 | 0.42 |
| 4 | Van Marum | 0.85 | 0.15 | 1.40 | 1.74 | 0.80 |
| 5 | Nairne | 0.32 | 0.30 | 0.18 | 0.30 | 0.60 |
| 6 | Holtz, ordinary | 0.55 | 0.14 | 0.45 | 0.36 | 1.25 |
| 7 | Same, with two plates | 0.55 | 0.14 | 0.86 | 0.72 | 1.20 |
| 8 | Same, inverse rotation machine | 0.30 | 0.09 | 0.23 | 0.24 | 0.97 |
| 9 | Carré, with ebonite plate | 0.50 | 0.13 | 0.21 | 0.29 | 0.72 |

As these results are all based upon an explosive distance of 1 millimetre, they become changed when the same is augmented. Thus the Van Marum and Nairne machines rapidly lose their advantage, while the Holtz machines retain the constancy of their yield. The three Ramsden machines are nearly equal, the advantages of Nos. 2 and 3 being mainly due to the quality of glass. It will be observed that the Nairne machine, despite its low yield in absolute value, is much more advantageous than the first three when the results are valued in ratio of the surface rubbed. This table, however, scarcely gives all the data for comparative estimates of value, because the various apparatus did not all have like speed of rotation. The frictional machines, the plates of which did not exceed 1 metre

in diameter, are easily turned once a second; but it is with difficulty that a machine 1.62 metre in diameter can be rotated faster than 40 turns per minute by one man. In the following table we give the velocities which cannot conveniently be exceeded. On this basis all electrical machines may be compared without regard to the principle on which they are made. The Armstrong machine referred to had 3 points of discharge, and operated under a pressure of 4 atmospheres. The induction coil, supplied by 8 large Bunsen elements, was capable of giving sparks 58 centimetres long. It had been employed to charge a battery over an explosive distance of 20 centimetres. Under these conditions each spark of the coil furnished nearly the same quantity of electricity as 5 turns of the plate of the Holtz machine; and as the coil gave 6 or more discharges per second, it was evidently equivalent to 3 Holtz machines.

*Table showing Results of Tests of Electric Machines.*

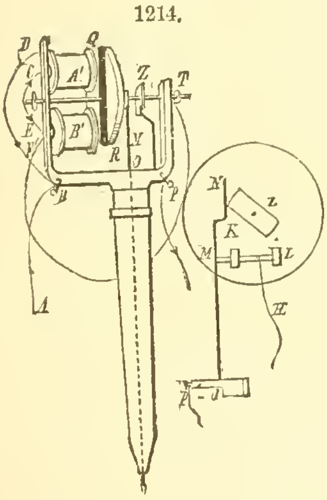
| NUMBER. | Machine. | Number of Turns per Second. | Yield per Second. | Yield per Unit of useful Surface. |
|---|---|---|---|---|
| 1 | Ramsden, Fig. 1199 | 1 | 1 | 0.42 |
| 2 | Same, larger | 0.67 | 1.14 | 0.26 |
| 3 | Same, with cylinders | 1 | 1 | 0.42 |
| 4 | Van Marum | 1 | 1.4 | 0.80 |
| 5 | Nairne | 2 | 0.36 | 1.20 |
| 6 | Holtz, ordinary | 10 | 4.5 | 12.8 |
| 7 | Same, with two plates | 10 | 8.6 | 12.3 |
| 8 | Same, inverse rotation | 10 | 2.3 | 9.7 |
| 9 | Carré, ebonite plate | 10 | 2.1 | 7.2 |
| 10 | Armstrong | ..... | 2.4 | ..... |
| 11 | Large induction coil | ..... | 13 | ..... |

This table shows plainly the superiority of modern machines. The induction coil really does not give much more electricity than a double Holtz machine; while if it be desired to obtain differences of potential notably greater, the Holtz machine appears much superior to the coil.

For a complete discussion of this subject, the reader is referred to "Traité d'Electricité Statique," Mascart, Paris, 1876, whence the above tables and many illustrations are taken. See also treatises classified under ELECTRICITY.

ELECTRIC PEN. This apparatus is the invention of Mr. T. A. Edison, and its object is the production of a stencil from which any number of copies of the writing made thereon can be produced. The pen consists of a metallic tube, in the centre of which a fine needle is reciprocated by means of a small electro-magnetic engine placed on the top of the pen. The current is transmitted to this engine through two fine wires connected with an electric battery. The battery is placed on the table or anywhere near the writer, and occupies but little space. The pen being held in an upright position, and moved over the paper, the rapidly succeeding thrusts of the needle cause the surface of the paper to become punctured with the characters which the hand has traced. After the writing is finished nothing but a faint line appears on the surface of the paper, but on holding it up to the light the writing is clearly visible. This sheet, which is called the stencil, is then placed over a sheet of plain paper in a frame, which, when closed, binds the two around their edges. An inked roller is then passed over it, and the ink penetrating the holes in the stencil transmits the written matter to the clean sheet, the lines being composed of a series of very fine dots. In this way, and by placing a number of sheets in succession under the stencil, about 500 copies or more in facsimile may be taken, each copy being very clear and distinct.

1214.

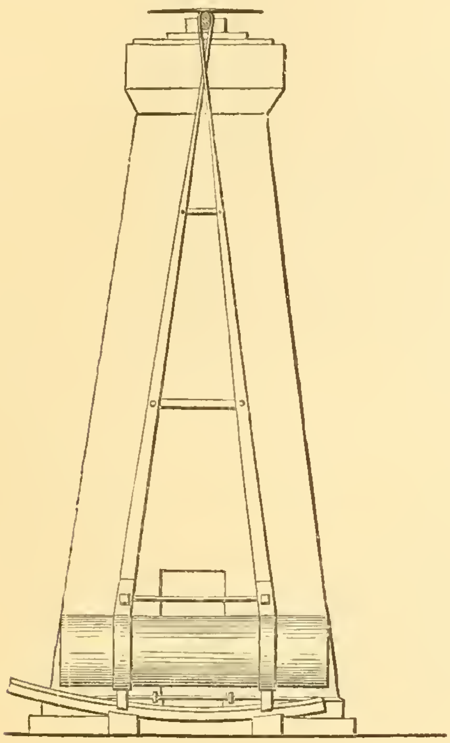


An end view of the pen is given in Fig. 1214. The current $A$ enters the engine by the binding-screw $B$, and thence passes by the wire $B\ D$ into the coil $A'$, which together with $B'$ forms an electro-magnet. On leaving $A'$ it traverses the wire $C\ E$, and enters the coil $B'$, and on leaving the latter passes to the screw $L$, and thence to the platinum point $K$; and when the latter is in contact with the other platinum point $M$ attached to the spring $N\ M\ O$, it returns by the binding-screw $P$ to the battery. $Q\ R$ is a small fly-wheel, on the axis of which at $Z$ there is a cam, which in certain positions of the wheel presses against the spring $N\ M\ O$, and so separates the platinum points $M\ K$, and at the same time interrupts the current. When the wheel has revolved half round, the cam no longer presses against the spring, and the current passes.

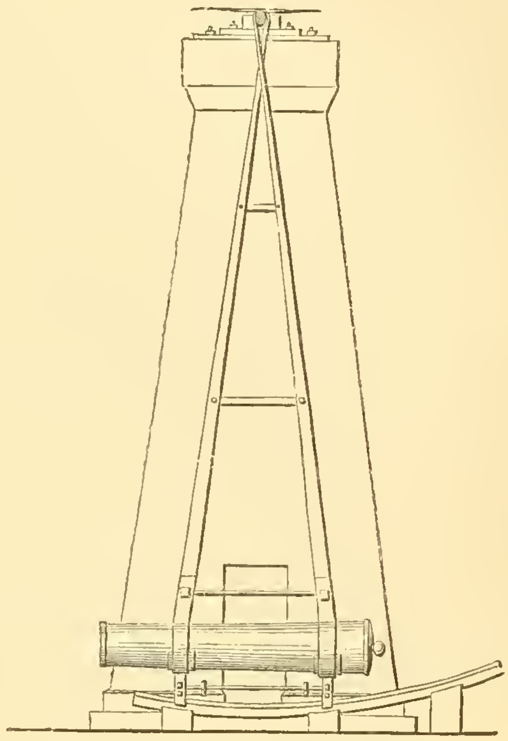
ELECTRO-BALLISTIC MACHINES. Apparatus for the determination of the velocity of a projectile at any point of its trajectory. (See ORDNANCE, and PROJECTILES.) The earliest contrivance for this purpose was the ballistic pendulum, which consisted of a tripod, from the top of which was suspended a pendulum vibrating freely on its axis of suspension, Fig. 1215. The bob was arranged to receive the impact of the projectile. The pendulum being at rest, it was struck by the projectile, a body of known weight. The degree of vibration due to the impact was then registered, and from this the velocity of the striking body was determined, the quantity of motion of the body before impact being equal to that of the pendulum and body after impact. The gun-pendulum, Fig. 1216, consisted of a cannon suspended in a horizontal position and vibrating freely, the arc of its recoil being accurately measured when the gun was fired. The quantity of motion of the gun as a pendulum is equal to that of the projectile, the charge of powder, and the air. From this the velocity of

the projectile may be deduced. A complete description of this machine, together with reference to the extended experiments made with it by Major Mordecai, U. S. A., will be found in the former editions of this work ("Appletons' Dictionary of Mechanics"). It has now given place to the very ingenious devices known as electro-ballistic machines, though in reality they are exceedingly delicate chronoscopes or measurers of brief intervals of time. Their operation is based either upon the action of gravity upon a falling body, the time being deduced from the space passed over during the inter-

1215.



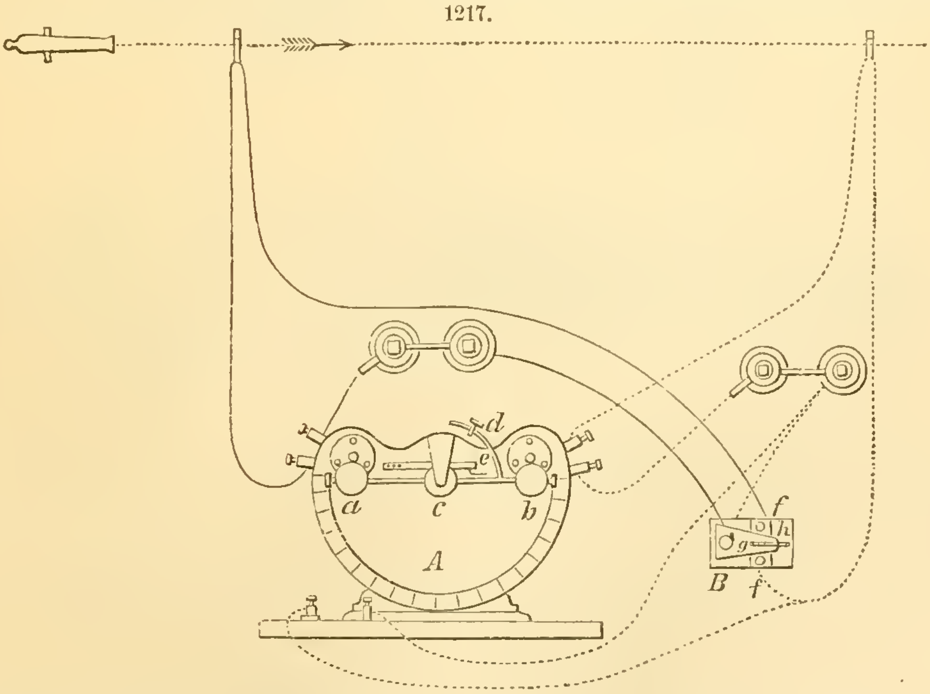
1216.



val to be measured; or upon the number of vibrations made by a tuning-fork during the interval of time to be measured, the rate of vibration of the fork being accurately known; or upon the direct action of electro-magnets upon a recording stylus, said magnets being demagnetized by the rupture of the circuit by the projectile.

To the first class of apparatus belong those dependent upon the pendulum, upon the free fall of a weight, upon the downward movement of a weight transformed into rotary motion, and upon the

1217.




escape of liquids. Examples of the second and third classes occur in the Schultz and Bashforth instruments, which will be described further on.

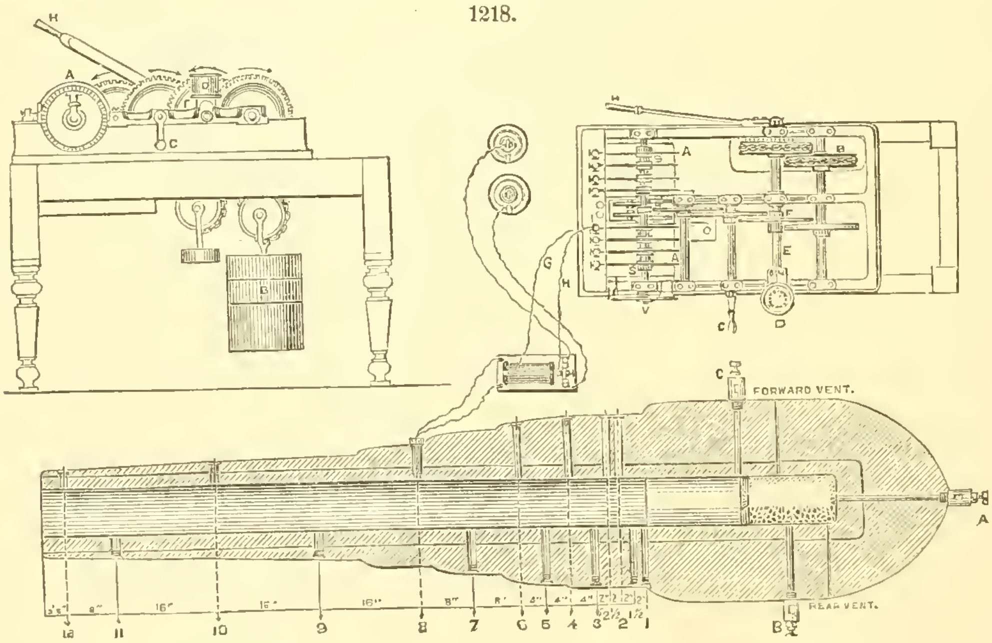
*Gravity Instruments.*—Of the pendulum apparatus the *Navez-Leurs Chronoscope* is the most successful. Two wire targets are placed in front of the gun so that the projectile passes through them, as indicated by the arrow in Fig. 1217. As the projectile passes through the first target it breaks a

circuit and demagnetizes the electro-magnet *a*. The pendulum-bob sustained by this magnet then begins to fall, carrying with it an index-needle. When the projectile cuts the wires of the second target, the second circuit is broken, and the magnet of the register-pendulum *b* is demagnetized. The bob falls, carrying with it an arc and stirrup *d*, which knocks away a wedge-lever and closes springs on a disk *e*, which clamps the index-needle. The time due to the arc of vibration is ascertained by the theory of the pendulum.

In the *Le Boulengé Chronograph* the shot is made successively to cut two currents, and thus to demagnetize two electro-magnets which had previously supported two heavy bodies; the fall of these bodies under the action of gravity is the measure of the time taken by the shot to pass over a known distance.

The principle of action of the *Noble Chronoscope*, Fig. 1218, consists in registering by means of electric currents upon a recording surface, traveling at a uniform and very high speed, the precise instant at which a projectile passes certain defined points in the bore. It is in two portions: the mechanical apparatus for obtaining the necessary speed and keeping that speed uniform, and the electrical recording arrangement. The first part of the instrument consists of a series of thin metal disks *A A*, each 36 inches in circumference, fixed at intervals upon a horizontal shaft *S S*, which is driven at a high speed by a heavy descending weight *B*, through a train of gearing multiplying 625 times. The precise rate of the disks is obtained by means of the stop-clock *D*, which can at pleasure be connected or disconnected with the revolving shaft *E*, and the time of making any number of revolutions of this shaft can be recorded with accuracy to one-tenth of a second. The speed usually attained in working this instrument is about 1,000 inches per second, linear velocity, at the circumference of the revolving disks, so that each inch traveled at that speed represents the thousandth of a second; and, as the inch is subdivided by the vernier *V* into 1,000 parts, a linear representation at the circumference is thus obtained of intervals of time as minute as one-millionth of a second. The arrangements for obtaining the electrical records are as follows: The revolving disks are covered on the edge with a strip of white paper, and are connected with one of the secondary wires *G* of an induction coil. The other secondary wire *H*, carefully insulated, is brought to a discharger *I* opposite the edge of its corresponding disk, and is fixed so as to be just clear of the latter. When a spark passes from the discharger to the disk, a minute hole is perforated in the paper covering (which is lampblacked) upon that part of the disk which was opposite the discharger at the instant of the passage of the spark. By means of the micrometer the distance between the sparks on the disks is read off. From this is known the time which the projectile occupies from the commencement of motion in reaching different parts of the bore, and from these time records may

1218.



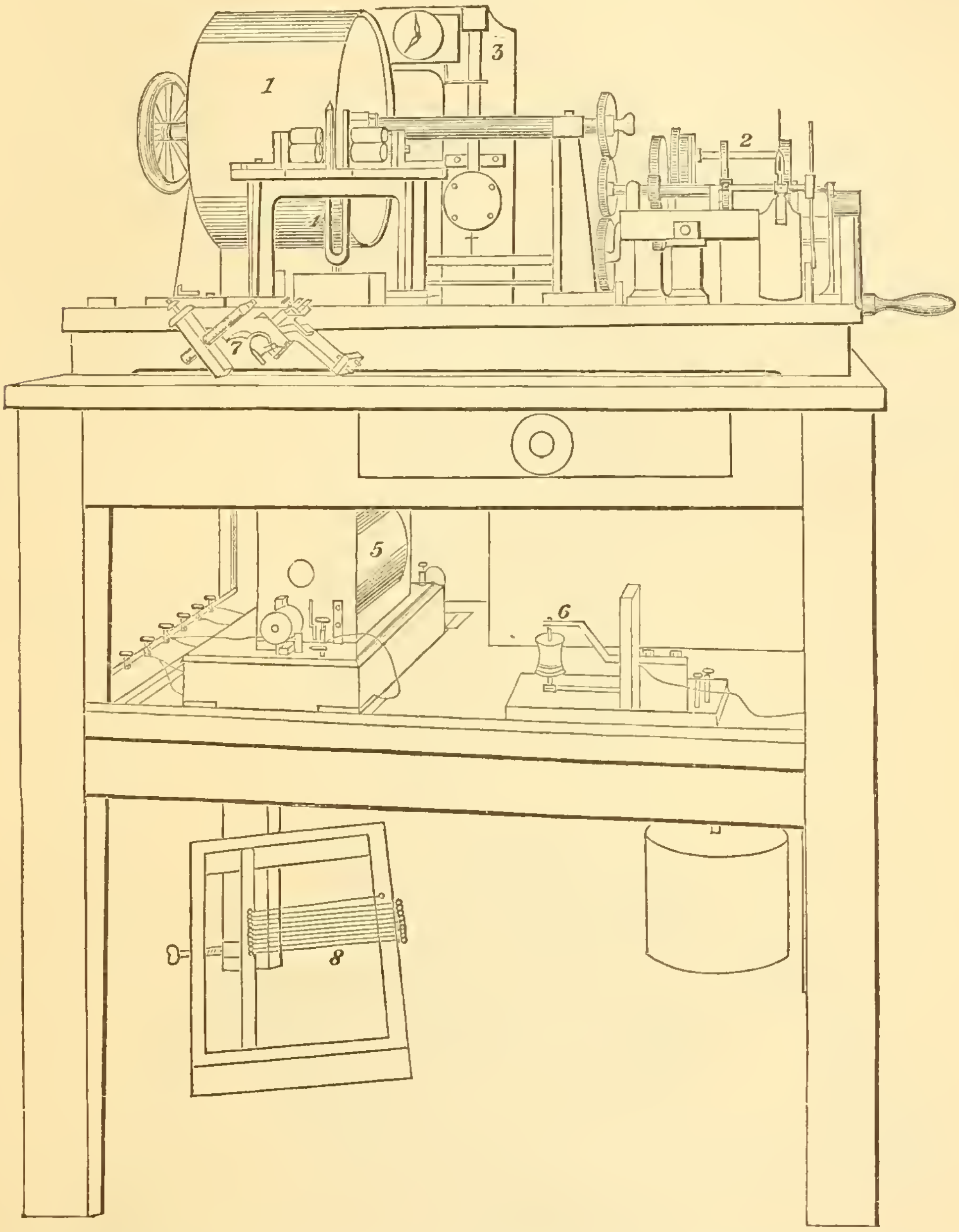

be deduced the velocity with which the projectile is passing through the different parts of the bore, and the pressures in the gun which correspond to these velocities.

*The Electric Clepsydra* measures time by means of the weight of mercury which escapes during the interval to be measured.

Vibration Instruments.—*The Schultz Chronoscope*, Fig. 1219, has a tuning-fork, making an ascertained number of vibrations per second, and arranged to trace on the blackened surface of a revolving cylinder a sinuous line showing the beginning and end of each vibration. This sinuous trace will be an actual scale of time. If, then, the instant the projectile reaches each of the two given points in its trajectory be marked upon the cylinder, beside the sinuous line or scale of time, the number of vibrations comprised between the two marks will be an exact measure of the time required. The general arrangement of parts will be understood from Fig. 1219, in which 1 is the blackened cylinder; 2, the actuating clockwork; 3, the pendulum; 4, the vibrating fork; 5, the Ruhmkorff coil; 6, the interrupter; and 7, the micrometer. At 8 the mode of construction of the target is shown. To use the Ruhmkorff coil, the primary wire is connected with the battery and the targets, and the secondary wire with the instrument. One of the ends is brought through a

glass tube close to the cylinder just over the fork; the other end is connected with the bed-plate and thence with the cylinder and other parts of the machine, except the support for the glass tube, which is insulated. By this arrangement, when the primary current is broken by the rupture of the target wire, a secondary current is induced, and a spark is projected from the end in the glass tube

1219.



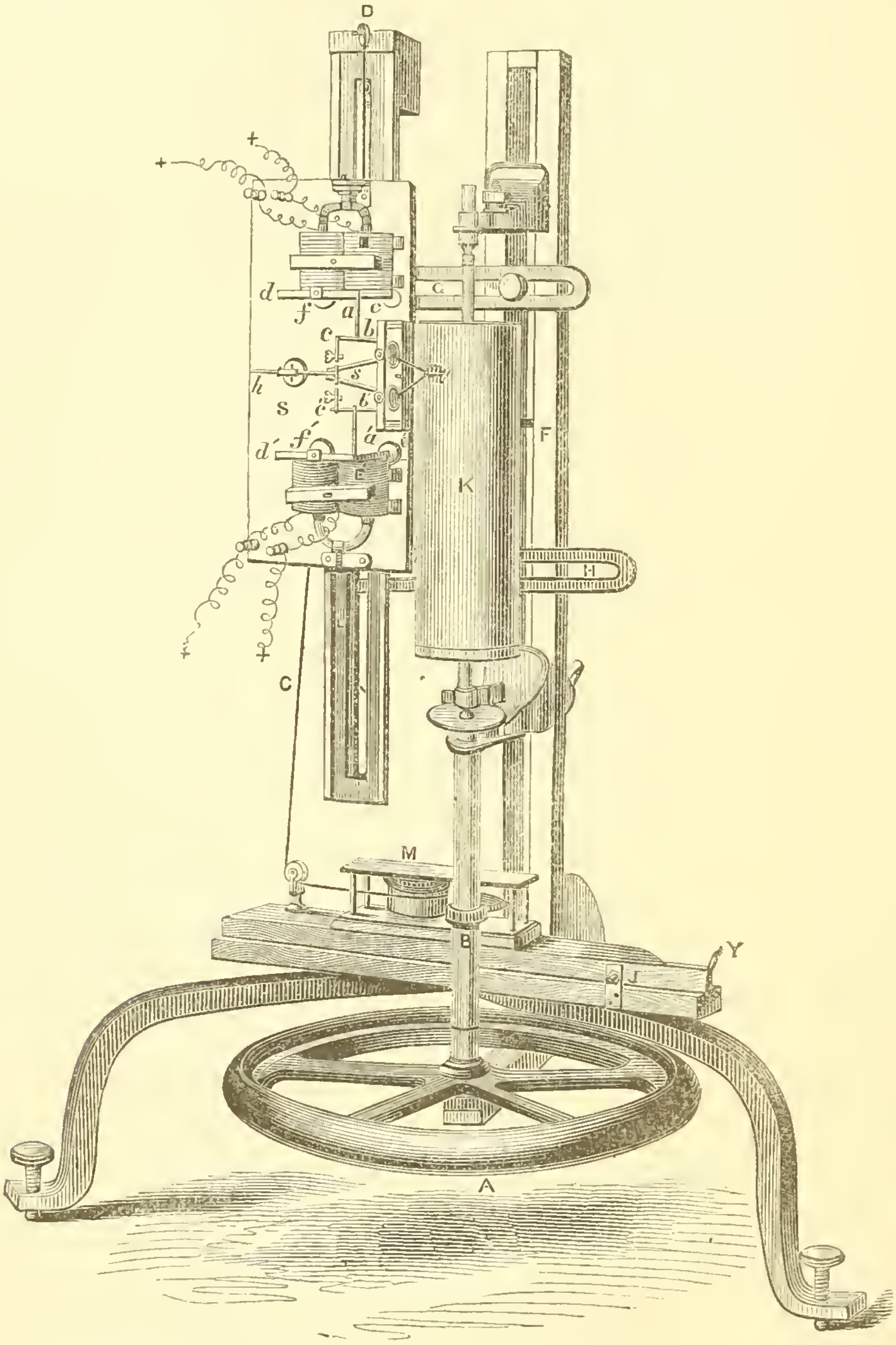

to the face of the cylinder, which represents the other end, where a bright spot beside the trace indicates the exact instant the rupture took place. The pendulum is used to determine the number of vibrations of the fork in a second of time; and the micrometer is used to divide a vibration on the cylinder into very small parts for close reading.

*The Bashforth Chronograph*, Fig. 1220, has a fly-wheel $A$, which revolves about a vertical axis, carrying with it the cylinder $K$, which is covered with prepared paper for the reception of the clock and screen records. The length of the cylinder is 12 or 14 inches, and the diameter 4 inches. $B$ is a toothed wheel which gears with the wheelwork $M$, so as to allow the spring $C\ H$ to be slowly unwrapped from its drum. The other end of $C\ D$, being attached to the platform $S$, allows it to descend slowly along the slide $L$, about a quarter of an inch for each revolution of the cylinder. $E\ E'$ are electro-magnets; $d\ d'$ are frames supporting the keepers: and $f\ f'$ are the ends of the springs, which act against the attraction of the electro-magnets. When the current is interrupted in one circuit, as $E$, the magnetism of the electro-magnet is destroyed, and the spring $f$ carries back the keeper, which, by means of the arm $a$, gives a blow to the lever $b$. Thus the marker $m$ is made to depart from the uniform spiral it was describing. When the current is restored the keeper is attracted, and thus the marker $m$ is brought back, which continues to trace its spiral as if nothing had happened. $E'$ is connected with the clock, and its marker $m'$ records the seconds. $E$ is connected with the screen, and records the passage of the projectile through the screens. By comparing the marks made by $m\ m'$ the exact velocity of the projectile can be calculated at all points of its course.

*Works for Reference.*—The foregoing illustrations and abridged descriptions are taken from " A

Text-Book of Ordnance and Naval Gunnery," by Commander A. P. Cooke, U. S. N., New York, 1875. See also "The Le Boulengé Chronograph," Michaelis, New York, 1872; "Electro-Ballistic Machines and the Schultz Chronoscope," Benet, New York, 1866; "The Determination of the Flight of Pro-

1220.



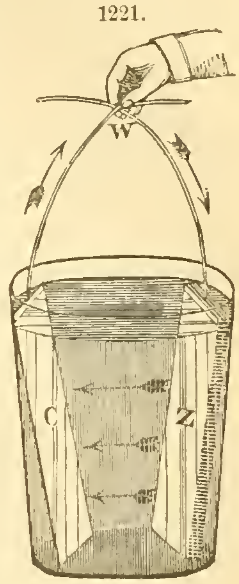
jectiles," etc., Le Boulengé (translated by Marvin), Washington, 1873. Also the various works referred to under ORDNANCE.

ELECTRO-GALVANIC AND THERMIC BATTERIES. I. GALVANIC BATTERIES.—When a piece of zinc is dropped into a vessel containing acidulated water, bubbles of gas are seen to issue from the metal, and the electro-dynamic impulses are propagated therefrom in every direction. By these counterbalanced opposite directions, the impulses neutralize each other's actions and reactions; consequently, no decided electro-dynamic action is perceptible. This experience was repeated thousands of times before the discovery of the galvanic battery arrangement, without developing electric excitation. But if a plate of copper or platinum, as at *C*, Fig. 1221, be placed opposite to the zinc *Z*, the impulses are determined through the water to the atoms of the copper plate, in one common specific direction. When the zinc is dissolving it gives off hydrogen and *heat*, while forming the more satisfied compound sulphate of zinc (the water being acidulated with sulphuric acid). The energy set free by the zinc entering into new combinations takes that form which we call electricity, instead of the other form which we call heat, and is capable of manifesting itself by its magnetic, chemical, or calorific effects (Sprague).

When the two free ends of the wire are brought in contact as shown, a current of positive electricity is generated, which, as indicated by the arrows, passes from the zinc through the liquid to the copper, and, traversing the copper plate from it, through the wires toward the zinc. At the same time a current of negative electricity is supposed to start from the immersed part of the copper plate, traveling

in the opposite direction through the liquid to the zinc plate, and out of the cell from the zinc by the wire connected with it toward the copper. The particles (molecules) of the liquid through which the current passes are supposed to undergo polarization, i. e., the separation of the electricity of the respective molecules, so that one half of each molecule becomes positively and the other negatively charged (Angell), by which their invisible transfer is effected.

1221.




*Definitions.*—The combination of parts above described constitutes a *couple.* Many couples connected form a *battery;* couples of certain forms are called *cells.* The two metals or their equivalents are called *elements*, the one most acted upon being always the *positive* substance, and the other the *negative.* The supposed positive electric fluid will, however, always come *out* from the negative. The liquid employed is commonly called the *exciting liquid.* That metal which has the strongest affinity for oxygen is usually the most electro-positive, and one metal may therefore bear an electro-positive relation to a second, while it is electro-negative when compared to a third. Potassium is the most electro-positive of all bodies, but its attraction for oxygen is so violent as to make it practically useless as an element in the galvanic circuit. Among those which can be usefully employed as electro-positive elements, zinc ranks first, while platinum is the most highly electro-negative metal. But the relative electrical condition of several of the metals changes when immersed in different liquids; thus, if an iron and a copper plate be connected with the electrodes of a galvanometer and immersed in dilute sulphuric acid, the needle will be deflected in one direction; while if the plates are immersed in a solution of sulphide of potassium, the deflection will be in the opposite direction. The following table shows a few of the results obtained by Faraday:

*Comparison of Different Metals in the Presence of Different Liquids.*

| Dilute sulph. acid. | Hydrochloric acid. | Sol. of potash. | Sol. sulphide of potash. |
|---|---|---|---|
| Silver. | Antimony. | Silver. | Iron. |
| Copper. | Silver. | Nickel. | Nickel. |
| Antimony. | Nickel. | Copper. | Bismuth. |
| Bismuth. | Bismuth. | Iron. | Lead. |
| Nickel. | Copper. | Bismuth. | Silver. |
| Iron. | Iron. | Lead. | Antimony. |
| Lead. | Lead. | Antimony. | Tin. |
| Tin. | Tin. | Cadmium. | Copper. |
| Cadmium. | Cadmium. | Tin. | Zinc. |
| Zinc. | Zinc. | Zinc. | Cadmium. |

The order in each column places the most positive metal in regard to the fluid at the bottom, and the most electro-negative at the top. It has been demonstrated by Poggendorff that the electromotive force between any two metals is equal to the sum of the electromotive forces between all the intervening metals.

The *conductive circuit* comprises the wires, instruments, etc., forming the path for the passage of the current (Prescott). *Resistance* is the opposition presented by the circuit to the development of the current; it is an inherent property of every substance, varying in degree in each substance, from silver, the best conductor, up to gutta-percha and other so-called non-conductors. The force of a battery, sometimes called the *tension* of the current, is the power which it has to transmit a current against resistance, such as that offered by a bad, long, or thin conductor, and is designated as its electromotive force. The unit of electromotive force is called a *volt.* The unit of resistance to the passage of an electric current is the *ohm*, and is about equal to that of a cylindrical wire of pure copper, .05 inch in diameter and 250 feet in length (No. 18 Birmingham wire gauge), or of 330 feet of No. 9 iron wire (.155 inch in diameter) of the average quality. The unit of the current is called a *farad*, and is equivalent to the quantity of electricity flowing per second in a circuit having an electromotive force of one volt and a resistance of one ohm. The quantity of electricity passing in a circuit, or the strength of the current, is estimated by the power of the current to deflect the magnetic needle, by the chemical decomposition it effects, or by the temperature to which it raises a wire of given thickness and material. The strength of the current must not be confounded with the strength of the element or battery which produces it. A battery of 100 cells has 100 times the electromotive force of a single cell of the same kind, yet in certain circumstances the one cell will produce as strong a current as the 100. The greatest quantity of current which a given galvanic element can produce is proportional to its surface. By doubling the size of the plates, the amount of current is doubled, provided the connecting-wire offers no appreciable resistance, and the quantity is not increased by increasing the number of cells. The electromotive force of a battery, on the contrary, is not affected by the size of plates, but by the number of cells in combination.

*Electrodes* is the term applied by Faraday to the poles or plates leading the current into and out of a cell. *Electrolysis* is the act of decomposition by an electric current. *Electrolytes* are bodies capable of being so decomposed (Sprague). *Ohm's laws* are formulas devised by Ohm for calculating unknown electrical magnitudes from certain given data. The symbols should represent fixed units to obtain definite results. They are as follows: 1. Current equals electromotive force divided by resistance. 2. Resistance equals electromotive force divided by current. 3. Electromotive force equals current multiplied by resistance. The chief *difference between frictional and voltaic electricity* consists in the fact that the latter is generated in very large quantities, but its electromotive force is so

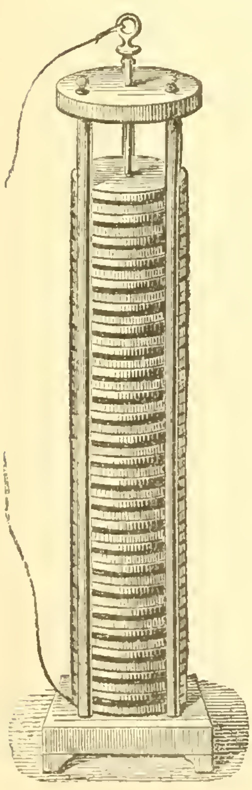
feeble as to render it incapable of overcoming a comparatively slight resistance; while the former, on the contrary, is generated in very minute quantities, but its electromotive force is so great as to enable it readily to overcome a resistance many million times as great as that which would entirely stop the passage of a current of voltaic electricity. The quantity of electricity which is denoted by unity in calculations based on electro-magnetic phenomena is nearly thirty thousand million times as great as the quantity denoted by unity when electro-static phenomena are taken as the basis of measurement.

*The Voltaic Pile.*—The voltaic pile of Volta, Fig. 1222, is constructed by placing upon a bottom piece of wood a disk of copper, and upon this a disk of cloth moistened with dilute acid or a solution of some salt, and upon this a disk of zinc, repeating the order indefinitely, one end of the pile terminating in a copper, the other in a zinc disk. In Cruikshank's battery, Fig. 1223, plates of zinc and copper are placed together in pairs and held in vertical grooves, all the zinc plates facing in one and all the copper plates in the other direction; the connection between the plates should be impervious to the fluid of the trough. This arrangement is really a horizontal voltaic pile.

*The Dry Galvanic Pile of De Luc* is constructed of sheets of paper, coated on one side with gold or silver leaf, and alternated with thin leaves of zinc. By means of a circular steel punch, about an inch in diameter, disks may be cut out of sheets of this paper foil, all of one exact size, adapted to be packed neatly together in a long glass tube. The atoms of the leaves of zinc very slowly become united with the atoms of oxygen of the air, recoiling to their natural polarized condition of groupings of an oxide, whereby a feeble propagation of electro-dynamic action is sustained during surprisingly long periods of time. Mr. Singer constructed a dry pile of 20,000 series of disks of silver, zinc, and writing paper, which propagated an intense electro-dynamic action, like that produced by frictional electrical machines, causing a pair of pith balls of an electroscope to become divergent. A pith ball suspended by a silk thread between two metallic knobs, one connected by a wire with the top cap of the pile, and the other with the lower cap of the pile, continued to vibrate unceasingly between the two knobs during several years. A thin glass jar containing 50 square inches of coated surface, charged by 10 minutes' contact with the column, was found by Mr. Singer to propagate sufficient electro-dynamic action to fuse one inch in length of platinum wire of the diameter of $\frac{1}{5000}$th part of an inch. He states that an efficient pile may be made of one kind of metal only, as of zinc foil, if one side be made bright, and thus rendered more readily oxidizable than the opposite surface.

The black oxide of manganese contains an extraordinary excess of oxygen, capable of freely uniting with zinc and other metals. Zamboni improved De Luc's pile by coating one side of the paper

1222.



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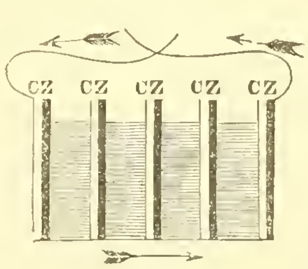


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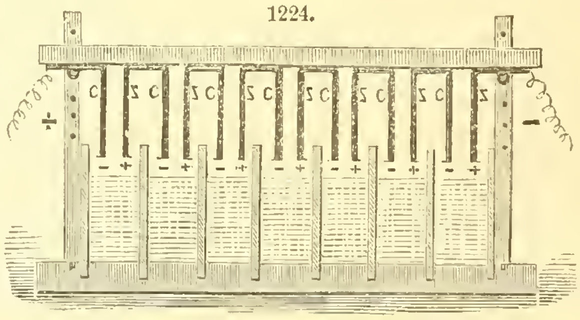

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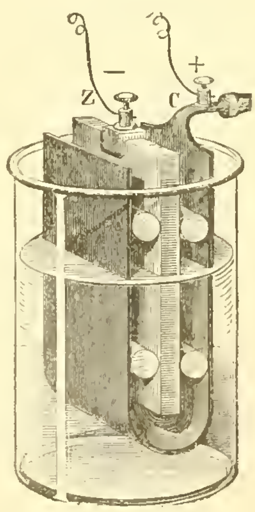
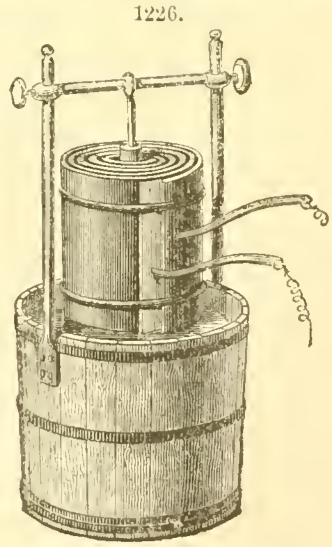



1226.



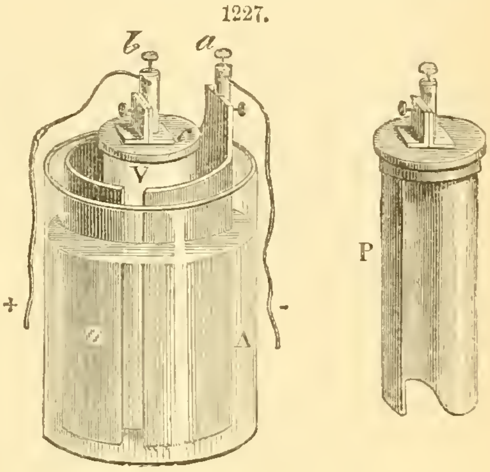
disks with this substance, mixed with sulphate of zinc, and the other side with tin foil. These piles are capable of developing sparks across a space of air of one-sixteenth of an inch, and also of producing chemical decompositions.

A common form of battery, which is merely a modification of Cruikshank's, is represented in Fig. 1224. It consists of a wooden trough divided into separate compartments containing the exciting fluid, into each of which are suspended a zinc and a copper or a zinc and a platinum plate, from a

horizontal wooden beam, the opposite elements in each compartment being connected together. The beam slides in vertical grooves in posts at the end of the trough, by which means the plates may be raised out of or lowered into the liquid. They may also be easily removed from the beam and cleaned or amalgamated with mercury, an operation which it is essential to perform with zinc plates which are not of pure metal; and, it not being practical to procure this, the operation of amalgamation is therefore universal. It consists in applying metallic mercury to the cleared surface of the zinc plates, by which the pure zinc becomes dissolved and brought to the surface, where the action of the acid is confined. In impure unamalgamated zinc local polarization takes place, forming local currents which greatly diminish or annul the electromotive force. A modification devised by Wollaston consisted in having a sheet of copper brought around one end of a zinc plate and separated from it by pieces of cork. Any number of couples can be united by using a trough divided into compartments, or by employing a number of glass or earthen cups such as are represented in Fig. 1225.

*Hare's Deflagrator*, Fig. 1226.—A powerful form of battery for heating purposes, in consequence of the immense quantity of electricity it generates, was constructed by Prof. Hare of Philadelphia, and consists of one or only a few simple couples, having a great metallic surface. A large sheet of zinc of several hundred square feet of surface, and a similar one of copper, are separated by a piece of felt or cloth saturated with acidulated water and then rolled together in the form of a cylinder.

1227.

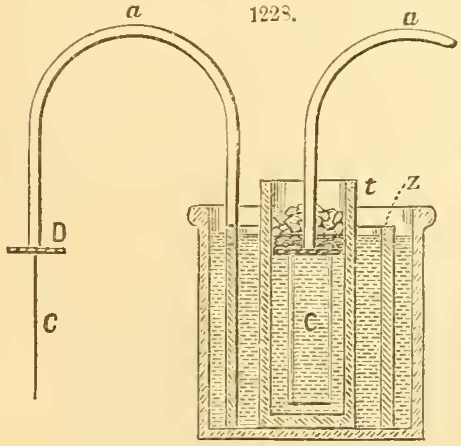



*Grove's Element*, Fig. 1227.—A glass or earthen vessel *A*, containing dilute sulphuric acid, receives a cylinder of zinc, within which is a porous earthenware cup *V* containing strong nitric acid, and in which there is immersed a platinum plate *P*. A cover attached to it confines the fumes of hyponitric acid, which are liberated by the decomposing nitric acid. The electromotive force is 1.956 volt.

The *Sesquioxide of Iron Element* of Messrs. Clamond and Gaiffe is composed of a prism of charcoal which contains sesquioxide of iron in its pores, and a small rod of amalgamated zinc. The latter passes through the stopper, in the under surface of which is fixed the charcoal. A solution of ammonium chloride is used as the exciting liquid. The reactions are the same as in Leclanché's couple, where oxide of manganese is used. Its electromotive power is as 12 to 10 of the sulphate-of-copper battery, and it is thus well adapted for industrial purposes.

The *Daniell Improved Element*, Fig. 1228.—A porous-clay cylinder *t* is surrounded by a zinc cylinder *z*. Within the former is suspended a thin sheet of copper, which is attached to the copper wire *a*, connected to the zinc cylinder of the next cell. At the upper part of the copper sheet *C* a sieve-like perforated copper plate is attached, which serves to hold the sulphate-of-copper crystals. The glass vessel and porous cup of each cell is filled with water, and the crystals of sulphate of

1228.

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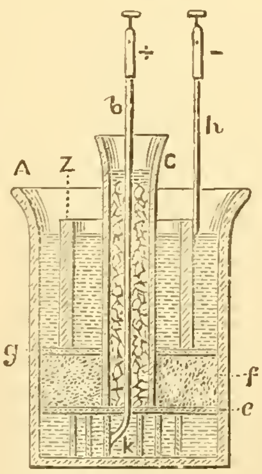


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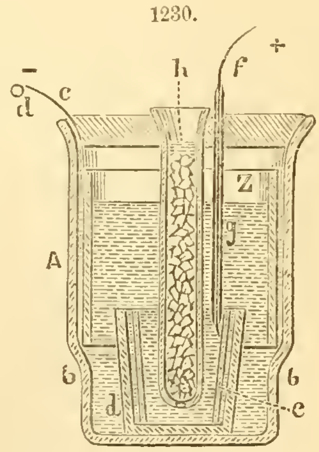



copper are placed as stated. Adapted for electro-deposition, gilding, silvering, electro-magnets, and large telegraphs; scentless, develops no poisonous vapors; electromotive force in volts, 1.08.

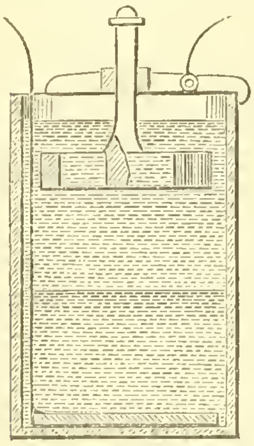
*The Siemens-Halske Element*, Fig. 1229.—*A*, glass vessel; *c*, glass tube; *k*, perpendicular copper plate bent in spirals; *b*, wire attached to it; *e*, thin pasteboard disk; *f*, diaphragm in place of porous cell in Daniell's battery, formed of a peculiarly-prepared mass of paper *z*; *h*, zinc ring, with clamp. Inner glass cylinder filled with crystals of sulphate of copper and water poured on. Ring-shaped intermediate space filled with water, to which on first filling is added acid or common salt. Quite constant, cheap, owing to prevention of chemical consumption of zinc and copper. Adapted for working long telegraph-lines; electromotive force same as Daniell's.

*The Meidinger Element*, Fig. 1230.—*A*, glass vessel, in which is placed cemented small glass vessel *d*, surrounded by zinc disk *Z*. Inside wall of *d* covered by copper sheet *e*, to which insulated

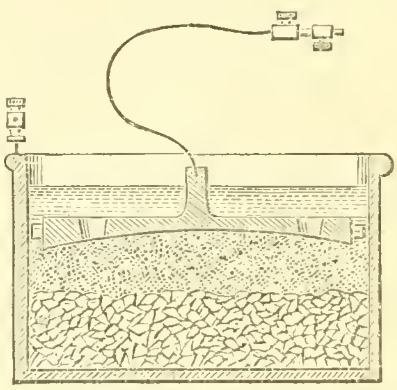
copper wire $g$ is riveted. Mouth of vessel closed by wooden plate, which receives glass cylinder $h$, having an opening below. This is filled with sulphate-of-copper crystals. Large vessel filled with diluted solution of Epsom salts. Valuable where long duration and a current of moderate but constant strength is required, and especially so for operating Morse telegraph, electrical clocks, hotel telegraphs, and electric bells. Electromotive force same as Daniell's.

*Gravity Element*, Fig. 1231.—A cylinder of zinc is suspended near the top of a glass jar, and a copper plate is placed at bottom. Jar filled with saturated solution of sulphate of copper and a

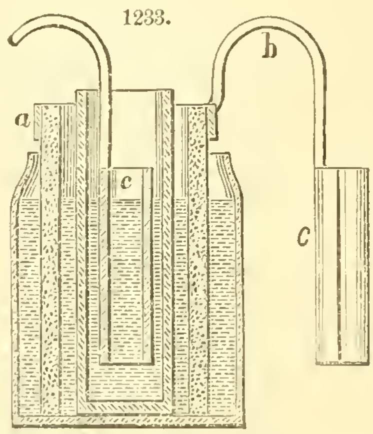
1231.



1232.



1233.




dilute solution of sulphate of zinc. The difference in the specific gravity of the two solutions causes them to separate at once and become superposed in the jar, the sulphate of copper occupying the lower and the sulphate of zinc the upper portions. Does not have the inconvenience experienced in use of Daniell battery from deposit of copper on porous cell. Electromotive force same as Daniell's.

An improvement on this form of battery has been devised by Edison, and is extensively used on telegraphs in this country. The modification consists in preventing the diffusion of the two liquids through each other by placing the copper element on top of a large quantity of the crystals of sulphate of copper, the tendency to diffusion being checked by the decomposition of the sulphate of copper.

*Callaud's Element* is constructed on the gravity principle, and works constantly for some months if care is taken to replace water lost by evaporation. It consists of a glass or earthenware vessel in which is a copper plate soldered to a wire insulated by gutta-percha. On the plate is a layer of crystals of sulphate of copper. The whole is then filled with water, and the zinc cylinder immersed in it. The lower part of the liquid becomes saturated with sulphate of copper. The action of the battery is that of a Daniell, and the sulphate of zinc which gradually forms floats on the solution of the sulphate of copper owing to its lower density.

*Sir William Thomson's Element*, Fig. 1232, consists of a containing vessel of sheet lead, in the bottom of which is placed 5 or 6 lbs. of sulphate of copper. This is covered with a layer of clean pine sawdust from 1 to 2 inches thick, upon which the zinc plate rests. The vessel is then nearly filled with soft water, or for quick action with a solution of sulphate of zinc. Remains constant, giving strong current for from three months to a year. Internal resistance low. Adapted for working circuits of small resistance, where comparatively strong and continuous currents are required.

*The Bunsen Element*, Fig. 1233.—This consists of a carbon cylinder, open at the bottom, placed in a narrow-mouthed glass vessel. In the hollow of the carbon cylinder is inserted a hollow porous-clay cylinder closed at the bottom. A ring $a$ is closely laid around the upper part of the carbon cylinder, and is attached to a hollow cylinder $c$, of rolled zinc. The porous-clay cup is filled with sulphuric acid, and the glass vessel with concentrated nitric acid. The zinc cylinder $c$, belonging to the next element of the battery, hangs in the porous cup filled with sulphuric acid. The positive current in this battery passes in the closing wire, outside the fluid, from carbon to zinc. The Bunsen element, like the Grove, develops a very powerful current, but it evolves a heavy deleterious gas. The carbons are sawn from the carbon deposited in gas retorts. A modification of the Bunsen battery is in use, in which a solution of bichromate of potash and sulphuric acid takes the place of the nitric acid. Electromotive force, nitric acid, 1.964; chromic acid, 2.028.

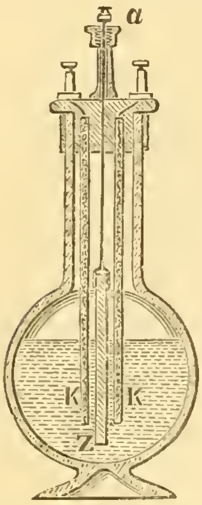
*The Grenet Element*, Fig. 1234.—This has a bottle-shaped cell, containing a mixture of 2 parts bichromate of potash, dissolved in 20 parts of hot water, and 1 part of sulphuric acid. To the wooden cover, which is inclosed in a brass frame, are attached two carbon plates, which permanently dip into the fluid; and between the carbon plates a zinc plate is suspended, which may be plunged into the fluid or withdrawn at pleasure. This element is not suitable for continuous use; but in all cases where a powerful current is required for a brief period, it may be economically employed. Electromotive force, 1.095.

*The Smee Battery*, Fig. 1235, consists of a strip of platinum, 1 inch wide by 10 in length, fastened to a beam of wood, upon the opposite side of which is a plate of zinc covered with mercury. Both are plunged into the glass vessel. $A$ is the wooden bar, $B$ brass clamps, $Z$ zinc plate, $P$ platinized silver plate or strips of platinum. Electromotive force when not in action, 1.090; in action, 0.482.

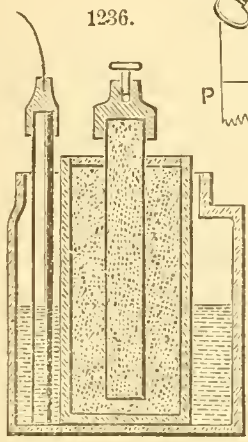
*The Leclanché Element*, Fig. 1236.—The + pole consists of a carbon plate, which on its upper end is coated with rosin and provided with a binding-screw; it stands in a porous cup, which is

filled with a coarse-grained mixture of the needle form of peroxide of manganese and carbon from gas retorts. The — pole consists of an amalgamated zinc rod. Both poles stand in a diluted solution of sal-ammoniac, which is poured into the outside glass vessel. There is no waste of material when the battery is not in action, so that, if the evaporation of the liquid is prevented, it may be allowed to remain untouched for months without losing power. It is well suited for a telegraph-wire not in

1234.




1236.



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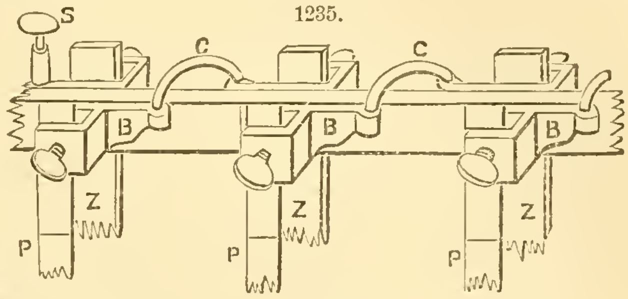


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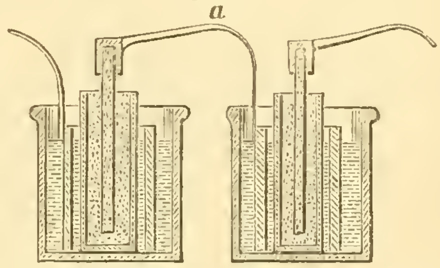
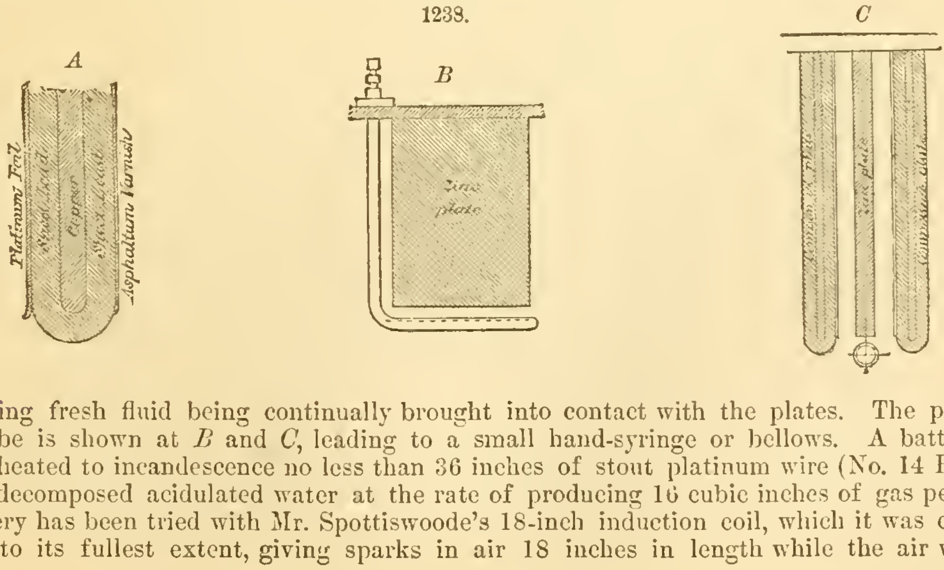



constant use, and worked upon the open circuit plan or for electric bells. It is not suitable for permanent currents or local circuits, because when placed in short circuit it polarizes very rapidly and loses power. Electromotive force, 1.481.

*The Marié-Davy Element*, Fig. 1237.—The zinc stands in pure water, and the carbon in a paste of moistened protosulphate of mercury in a porous cup. While this makes a powerful battery which produces excellent effects, its maintenance is expensive, and it is not adapted for continuous work, owing to the slow solubility of the salt. Electromotive force, 1.524.

*The Byrne Compound-Plate Battery.*—The special feature of this battery consists in the negative plate, which, instead of being of one material, is constructed of three different metals soldered together. The surface exposed to the exciting solution and opposed to the positive or zinc plate is platinum; this platinum is backed by and soldered to a plate of sheet lead; behind this again is a plate of copper backed by a fold of the first lead plate doubled on to the back of the copper. The back surface of this second layer of lead is coated with asphaltum varnish. The arrangement will be understood from Fig. 1238, in which *A* represents a vertical cross-section of the compound negative plate, the thickness of its laminæ being greatly exaggerated in order to show its construction. Each cell consists of a central zinc plate placed between two of the compound plates, as shown at *C*. The exciting solution consists of 5 ounces of potassium bichromate dissolved in 5 pints of boiling water, to which is slowly added when cold 1 pint of strong sulphuric acid. In the pneumatic form of the compound-plate battery the exciting solution is kept in a state of mechanical agitation by air being pumped into the cells through a perforated tube leading from each cell-cover to the bottom of the cell, where it turns at right angles, so as to lie in a horizontal position underneath and in a line with the central zinc plate and between the compound plates. Jets of air are thus injected into the cell, which, rising in the form of bubbles between the plates, keep the solution in violent agitation, washing off from the plates bubbles of hydrogen which otherwise would collect,

1238.




and insuring fresh fluid being continually brought into contact with the plates. The position of the air-tube is shown at *B* and *C*, leading to a small hand-syringe or bellows. A battery of 10 cells has heated to incandescence no less than 36 inches of stout platinum wire (No. 14 B. W. G.), and has decomposed acidulated water at the rate of producing 16 cubic inches of gas per minute. This battery has been tried with Mr. Spottiswoode's 18-inch induction coil, which it was capable of charging to its fullest extent, giving sparks in air 18 inches in length while the air was being

pumped in, but which fell to 8 inches when the air supply was cut off. Mr. W. H. Preece, C. E., has determined that the greatly increased current is due partly to the diminution of resistance in the compound plate, partly to a second diminution of resistance in the liquid itself caused by the passing of the air through it, and partly to the production of heat, which, by modifying the chemical affinity between the molecules of the solution, reduces its resistance. Mr. Preece's experiments lead him to the belief that the action of the air is principally and directly mechanical, and indirectly chemical; for by mechanical agitation it removes adherent hydrogen from the negative plate, as well as the chrome alum which is formed there, and, by causing a circulation in the liquid, brings fresh acid into contact with the zinc, thereby assisting its consumption, and by the generation of heat reduces the resistance of the solution, and again aids the acid in dissolving the zinc. (See *Engineering*, xxv., 417–421.)

*Trouvé's Portable Battery.*—M. Trouvé has devised a simple and cheap form of portable battery suitable for military telegraphing, etc., which contains from 40 to 80 elements. Each of the elements is composed thus: Between two disks, one of copper, the other of zinc, are placed a number of round pieces of blotting-paper. One half of the rouleau is saturated with sulphate of copper, the other half with sulphate of zinc. The elements are arranged for tension in a case of hardened caoutchouc, and about a commutator and galvanometer, the whole being inclosed in a mahogany box. When the apparatus is to be used, the elements are immersed in water, which, absorbed by the paper, dissolves the sulphate of copper and sulphate of zinc, producing the chemical action necessary to a current. The paper remains moist for a long time. To recharge the pile, it is sufficient to immerse it one half in sulphate-of-copper solution, since the sulphate of zinc is continually being produced. (See *Les Mondes*, xxxiii., 3; *Scientific American*, xxxvii., No. 21.)

*The Maynooth Battery* is essentially the same as the Grove battery, except that it has a plate of iron instead of platinum, and is therefore much cheaper.

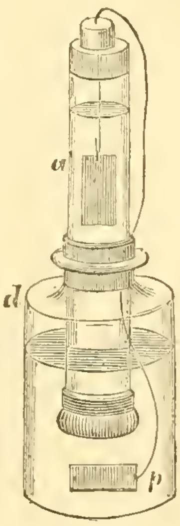
*Earth Batteries.*—These are simply voltaic couples in which the layers of acidulated cloth, etc., are replaced by a layer of moist earth. Large plates of copper and zinc have been buried several miles apart, and a powerful electric current has been found in a wire connecting them. The construction of such earth batteries, easy and simple as it appears to be, has never become a settled practice, by reason of the laborious digging required, it being much easier to plunge plates into cups and renew them after a while, than to dig up the oxidized zinc plates in order to replace them by new ones. However, when a brook or river is at hand, the use of earth batteries may be recommended, as in that case the zinc plate has only to be sunk at a convenient and safe spot. Then at any time, if the current becomes weak, the plate may be easily replaced by a fresh one, while in place of the copper a quantity of coke may be buried in the moist earth. The great objection to this form of battery is, however, the unavoidable total lack of intensity; as the latter quality depends upon the number of cups, and the earth or water acts as but one single cup, and thus the burial of several plates is equivalent only to the immersion of them in a single cup. If the plates are connected for quantity (that is, all the zincs together and all the coppers or cokes together), the series will act like a single pair, of which the surface is equal to the sum of the individual plates, and thus as one pair of large surface. If, on the other hand, the plates are connected for intensity (that is, every alternate zinc to the next copper), only the two plates at the extremes of the series will be of use, because the several intermediate pairs discharge mutually all the electricity generated into the moist earth through their metallic connections.

*Carbon-consuming Elements.*—It has been stated as probable that when the discovery shall have been made of how to oxidize carbon in the galvanic battery, the cheapest source of electricity will have been attained. Crookes's battery, in which carbon is claimed to be oxidized, consists of an iron ladle, which serves both as a containing vessel and as the non-attackable electrode. In this is melted nitrate of potash, and into the liquid thus produced carbon is plunged. The oxygen in the nitrate with the carbon produces carbonic acid, which unites with the remaining potash, forming carbonate of potash, and by the chemical action a current of electricity, which "affects the galvanometer," is liberated. A better current is obtained by a plate of platinum placed with the carbon in the fused salt. M. Jablochkoff has devised another form of carbon battery essentially the same as the foregoing. He rejects the platinum in favor of iron alone, and suspends his carbon in a wire basket in the liquid; but he says that by adding different metallic salts he is enabled to vary the power of the battery and the rapidity of expenditure of carbon, and with these salts there is received a galvano-plastic deposit of the metals on the non-attackable electrode. The electromotive force of the battery is stated to vary between 2 and 3 units, according to the nature of the metallic salts used.

*Becquerel's Two-Liquid Element.*—Fig. 1239 represents a galvanic couple composed of two liquids and one metal, devised by Becquerel, and called an oxygen circuit. A bottle, *d*, contains nitric acid, and into its mouth is inserted a tube containing a solution of caustic potash, and having a cork in the top through which passes a wire. The bottom of the tube is stopped by a piece of linen cloth, which is covered with clay, and this with cotton wool, to prevent the clay from mixing with the liquid. The wire connects two plates of platinum, *a* and *p*, and the connection may be made through the coil of a galvanometer if it is desired to measure the strength of the current. The two liquids meet each other in the clay, and a current of considerable strength is generated, which passes through the wire from the acid to the potash solution, and through the clay from the potash solution to the acid; the latter answering to the copper plate of an ordinary couple, and the potash solution to the zinc. The water in the potash solution is decomposed, its oxygen escaping in bubbles, and its hydrogen going to the nitric acid, which it reduces to nitrous acid. The current which is generated is of constant strength, and the plates do not become polarized. The power is increased by making the plate in the potash solution of amalgamated zinc, which being attacked by the nascent oxygen produces polarization in the direction of the current. A simple couple of this kind is sufficient to effect the electrolysis of water, and several couples form a powerful battery.

*Gas and Secondary Batteries.*—In the electrolysis of water or any body which causes oxygen to be evolved at one electrode and hydrogen at the other, a thin film of gas becomes attached to each plate, having sufficient electromotive force to send a current in the contrary direction when the battery is removed and a connecting-wire introduced. Such currents, produced by polarized plates, are called secondary currents; and upon this principle Prof. Grove constructed a gas battery which is capable of producing a continuous current. Two glass tubes, Fig. 1240, closed at the top, each contain a strip of platinum, which is suspended by a platinum wire passing through the top of the tube. The surfaces of the strips present the metal in a finely divided state. The tubes at their upper extremities are closely sealed and filled with dilute sulphuric acid, and their lower ends, which are open, are placed in the same liquid in the vessel *a a*. The platinum strips are then connected with the poles of a battery, and by electrolysis hydrogen is collected in one tube and oxygen in the other. Upon removing the battery and connecting the platinum strips either through a galvanometer or an easily decomposed electrolyte, as iodide of potassium, a current will flow from the oxygen to the hydrogen tube, and in the opposite direction to that produced by the battery used in evolving the gases, while during the action the gases in the tubes will gradually disappear, the hydrogen twice as fast as the oxygen. Ritter's secondary pile is constructed upon the same principle. A number of disks of the same metal are separated by pieces of moistened cloth. After passing for a time a galvanic current through the system, on removing the battery and connecting the ends of the pile a current will be found passing in the opposite direction to the battery current.

1239.

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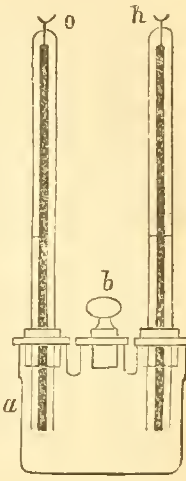
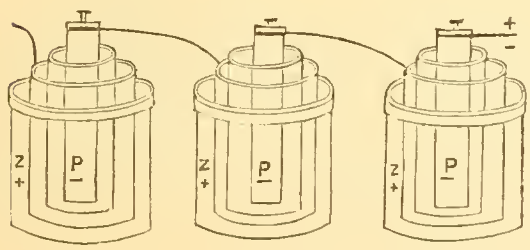
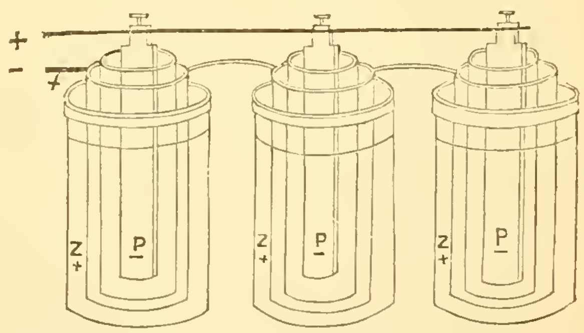



M. Gaston Planté has devised a secondary element, which consists of a tall vessel of glass, gutta-percha, or ebonite, in which are placed two sheets of lead, rolled spirally, and parallel one to the other, and kept from touching by two cords of India-rubber rolled up with them; they are immersed in a solution of 1 part of sulphuric acid to 9 parts of water. The vessel is closed by a sealed cover pierced with a small hole, through which the liquid can be poured in or extracted, and which also allows the escape of any gas which may be generated during the charging of the battery. The

1241.




1242.




apparatus is surmounted by a disk of ebonite, upon which are fixed two contact pieces in connection with the two electrodes; two clips are also provided for the purpose of holding metallic wires to be made red-hot or melted by the secondary current. Two Bunsen cells, or in their stead three Daniell cells, are required to charge this secondary element. During the operation of charging, one of the electrodes oxidizes, a brown coating of peroxide of lead soon shows itself, and the metallic appearance disappears entirely; the other electrode also changes in appearance, its surface becoming covered with a powdery gray coating. When the charge has attained its maximum—that is to say, when oxygen begins to be given off by the brown electrode—the secondary element is disconnected from the charging battery, for any further expenditure of the polarizing current is entirely wasted. The secondary element, once charged in this manner and left to itself, will retain a portion of its charge for several days; and even at the end of a week it is still far from being exhausted. The secondary element, when fully charged, has an electromotive force once and a half greater than that of Bunsen; it will redden a platinum wire of a greater or lesser diameter according to its size, or rather according to the size of the electrodes. Secondary elements can be joined together either for intensity or quantity, and form batteries capable of producing very powerful effects for short periods of time. (See *Scientific American Supplement*, i., 65. As to effects of large numbers of these elements when coupled together producing the electro-silicic light, see *Scientific American*, xxxviii., 313.)

*Connection of Elements in Batteries.*—The coupling of elements to overcome external resistance is represented in Fig. 1241. This is termed coupling for intensity or in series, and is the arrangement adopted in telegraph batteries and in galvanoplastic operations. Coupling for quantity is represented in Fig. 1242, where plates of the same metal are grouped together. It has the same effect as the employment of one pair of plates having an equal area of surface.

*Discharges from Great Numbers of Cells.*—Some remarkable experiments showing the effects of discharges of great numbers of cells have been made by Messrs. Warren de la Rue, Spottiswoode, and Muller. (See *Proceedings of the Royal Society*, No. 160, 1875, and No. 166, 1876.) The element

consisted of a flattened wire of silver and a rod of zinc. At one end of the silver a cylinder of chloride of silver was cast. In order to prevent contact between the rods of zinc and chloride of silver, the latter was surrounded with a cylinder open at top and bottom, and made of vegetable parchment. The cell was a glass tube, the stopper a cork saturated with paraffine, and through which a rod of non-amalgamated zinc was inserted. The exciting liquid was a solution of 23 grammes of chloride of ammonium to 1 litre of water. On examining the length of discharge from various numbers of these elements, its length was found to be in the direct ratio of the square of their number, as follows:

| No. of cells. | Striking distance. | No. of cells. | Striking distance. |
|---|---|---|---|
| 600 | .0033 inch. | 1,800 | .0345 inch. |
| 1,200 | .0130 " | 2,400 | .0535 " |

These are very nearly the squares of the number of cells. As the experiments were carried further, it was found that the striking distance probably increases in far greater ratio. Taking as a basis the spark with 600 cells = .0033 inch, the investigators point out that a unit of 1,000 such cells would give a spark of $\frac{.0033 \times 1000^2}{600^2} = 0.009166$ inch; one hundred units (100,000), a spark of 91.66 inches; and a thousand units (1,000,000), a spark of 9,166 inches, or 764 feet—nearly a true flash of lightning, not only in distance but in quantity. With 5,640 cells sparks were obtained over .139 and .140 inch; and other phenomena were noted, which will be found described in detail in the references above given.

An excellent series of lectures on the voltaic battery by Dr. Gladstone, F. R. S., appears in the *Telegraphic Journal*, iii., 14. See also the list of works for reference given under the general heading of ELECTRICITY.

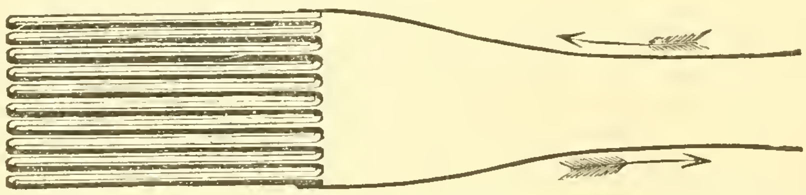
II. THERMO-ELECTRIC BATTERIES.—Whenever two pieces of unlike metal are heated together and the parts not heated are joined, a current passes through the whole circuit. The direction which this current takes is always reversed if, instead of being heated, the place of contact of the two is cooled. In the following table the metals are arranged in such order that, on heating the point of contact of any pair, the current passes through the point of contact from the one above to the one below:

| | | | |
|---|---|---|---|
| 1. Bismuth. | 8. Manganese. | 15. Molybdenum. | 22. Platinum (3). |
| 2. Nickel. | 9. Titanium. | 16. Rhodium. | 23. Cadmium. |
| 3. Cobalt. | 10. Mercury. | 17. Indium. | 24. Steel. |
| 4. Palladium. | 11. Lead. | 18. Gold. | 25. Iron. |
| 5. Platinum (1). | 12. Tin. | 19. Silver. | 26. Arsenic. |
| 6. Uranium. | 13. Platinum (2). | 20. Zinc. | 27. Antimony. |
| 7. Copper. | 14. Chromium. | 21. Tungsten. | 28. Tellurium. |

In experimenting with thermo-electric batteries formed of plates of bismuth and antimony, the bismuth being fusible at a low temperature, a very moderate heat must be applied. For this reason German silver and brass are preferred, as they admit of being safely excited by the contact of the red-hot iron, which will melt the bismuth.

To render the arrangement of the series of plates or wires of a thermo-electric battery more compact, they are laid side by side, as shown in Fig. 1243. They are insulated from each other by pasteboard, except at the ends, where the respective plates of bismuth and antimony, or of German silver and brass, are alternately soldered together, as in the arrangement of the series of plates of a

1243.



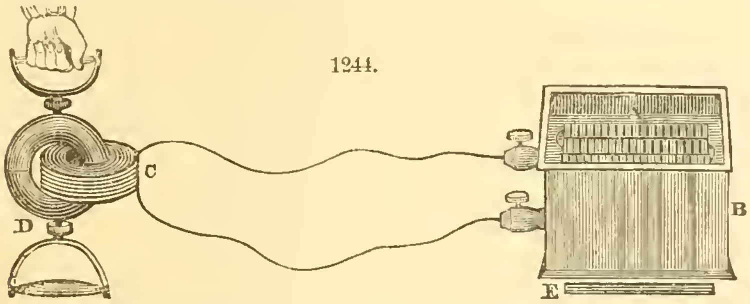
voltaic pile. Fig. 1243 represents a series of 10 pairs. The heat of the palm of the hand held in contact with the soldered ends of this battery induces sufficient excitation to affect a galvanometer needle.

A more perfect thermo-electric battery is commonly constructed as exhibited in Fig. 1244, consisting of 60 pairs of plates of bismuth and antimony, each three-quarters of an inch broad and one-quarter of an inch thick. They are packed together in a case *B*, but are insulated from one another, except at the soldered junctions of their ends, as above stated. The soldered ends of one series are arranged together on the under side of the case, where they may be heated by the radiation of the hot iron plate *E*, the edge of which only is exhibited in the cut. The opposite series of the soldered ends are arranged together on the upper side of the case, as seen at *A*, which forms a reservoir for receiving a refrigerating mixture of snow or ice and table salt. The plates are insulated from each other, and from the case, by pouring fluid plaster therein; which also serves to render the consolidated mass impervious to the water resulting from the melting ice. By thus combining two extremes of temperature at the opposite ends of the plates, there is produced a correspondingly extreme disturbance of the temperature of the plates, and development of electric forces, as tested by the two conjoined iron semicircles *D*, environed by a coil of the conducting-wire *C*, whereby "a weight of 40 or 50 lbs. is required to separate them." Indeed, this thermo-electric battery is adequate to

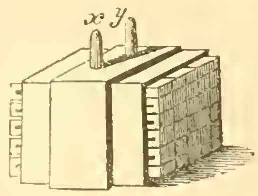
exhibiting various electro-magnetic phenomena which a galvanic battery is commonly used to exhibit, and also to give shocks and sparks.

The mechanical forces brought into action upon the needle of a galvanometer by slight disturbances of temperature have been illustrated in an interesting manner by the experiments of Nobili and

1244.

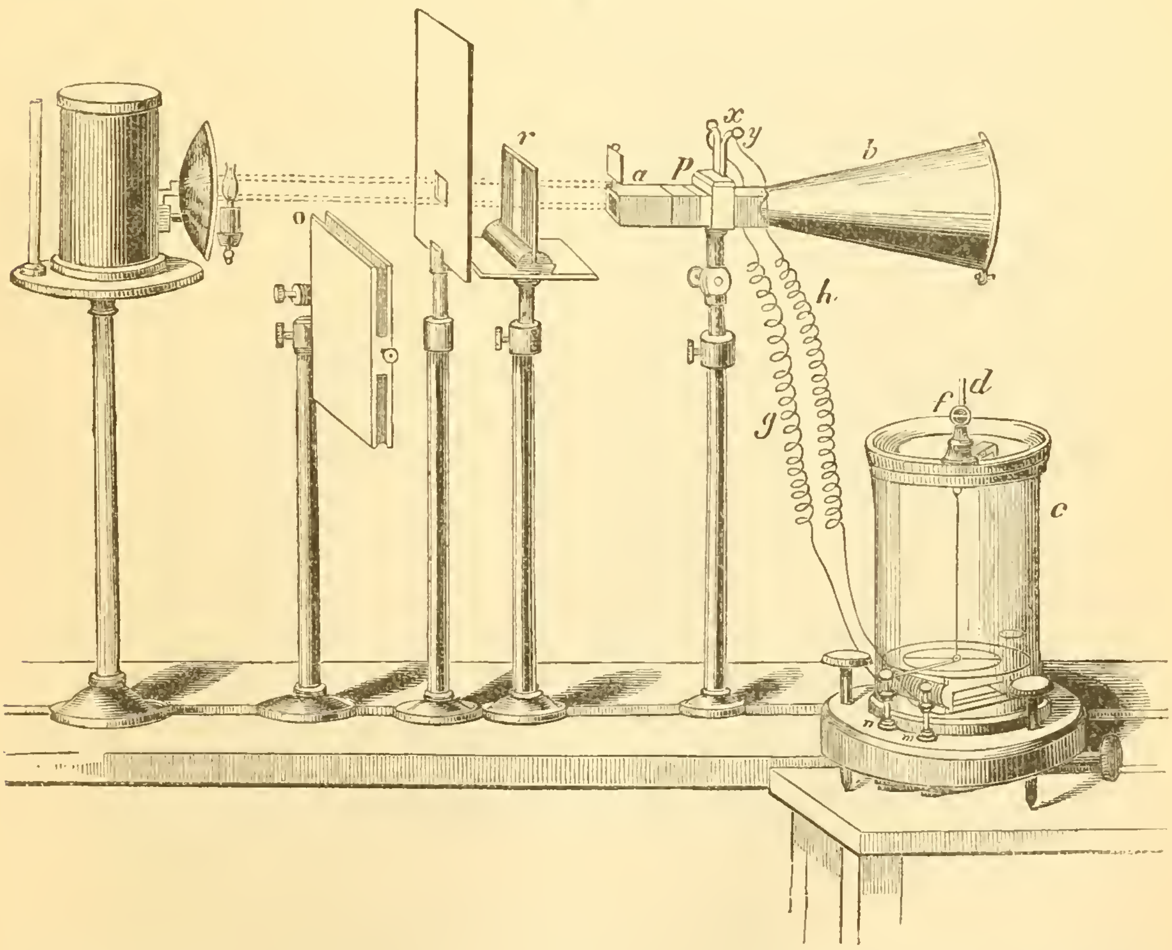



1245.




Melloni. The thermo-electric battery employed by them consisted of 50 small bars of bismuth and antimony, forming a bundle about $1\frac{1}{2}$ inch long and about 1 inch in diameter, inclosed in a band, as shown in Fig. 1245. To facilitate the radiating and imbibing properties of the two extremities of the bundle of bars, the conjoined ends are all blackened. The extremities of the circuit are terminated at the two poles $x$ $y$. The bars of antimony and bismuth are insulated from each other by coatings of dry paper or silk throughout their lengths, and are soldered together alternately at their ends. The terminating bar of each series is separately connected with the ends of a wire forming the coil beneath the galvanometer $n$ $m$, Fig. 1246, in the same manner as the copper and zinc plates of a galvanic battery are connected by the wires $g$ and $h$ with the battery poles $x$ $y$ of Fig. 1245. In the position of the instrument indicated in the figure, it is intended to denote at $p$ the blackened ends of the bars of the thermo-electric series, heated by a lamp with a reflector. The dotted lines represent the radiation of the heat through the aperture of the screen $r$, while the temperature of the other ends of the bars $p$ remains the same as that of the surrounding air. The heat of the lamp induces a disturbance in the electrical equilibrium of the bars of antimony and bismuth. The electricity is determined to move in one uniform direction in a closed circuit through the conducting-

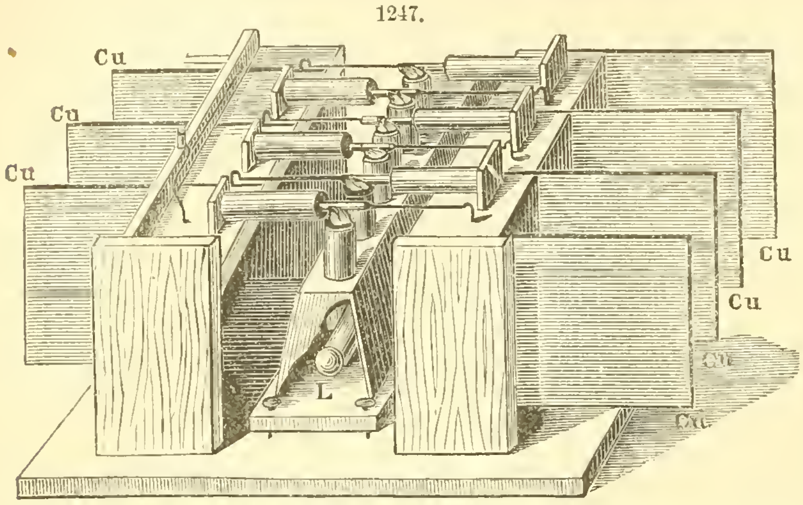
1246.




wires soldered thereto, and through the coil in proximity to the galvanometer needle, which is thereby swung around on its pivot. To prevent local disturbances of the needle by currents of air, the galvanometer is inclosed under a bell-glass, and is suspended from $d$ by a very flexible fibre of silk. At $o$ is a movable screen, designed to intercept the propagation of heat from the lamp when an experiment is suspended. The least radiation of heat from a lamp, or from the bodies of living animals,

presented before the aperture of this instrument, causes the needle of the galvanometer to move around on its pivot. This thermo-electric battery, taken in connection with the appended galvanometer, constitutes a far more sensitive test of the approach of a warm body than the most delicate thermometer. The approach of a person within 30 feet of it causes the needle to move, as stated by Nobili and Melloni. The slight heat of the bodies of insects, of phosphorescent wood, putrefying fish, etc., was thus detected.

1247.




*Noe's Pile*, Fig. 1247, consists of small cylinders, about $1\frac{1}{4}$ inch long and three-eighths of an inch diameter, of an alloy of about $36\frac{1}{2}$ parts of zinc and $62\frac{1}{2}$ of antimony as the positive, and stout German-silver wire as the negative element. Twelve of these pairs have an electromotive force of one Daniell's cell, and 20 of them that of one Bunsen. The resistance of 20 of them is about equal to one ohm. With a great external resistance, 20 of them are equal to one Bunsen's; and with a small external resistance, 20 *quadrupled* ones are somewhat stronger than one of Bunsen's elements. The construction of a few elements is shown in the figure. The junctions of the elements are heated by small gas-flames, and the alternate junctions are cooled by the heat being conducted away by large blackened sheets of thin copper. To protect the German-silver wire from oxidation, it is inclosed in a tube of that alloy where the flame impinges against it; and to prevent the ends of the positive cylinders being melted, they are faced with iron and a thin sheet of mica. The German-silver wire may be heated to low redness. The usual form of the apparatus is in 96 elements, which may be used either as 96 by 1, 48 by 2, or 24 by 4, and instantly changed from one to the other of these arrangements by means of a most ingenious and effective current-transposer, which does not require cleaning. The current attains its maximum strength in about one minute; that from the single series decomposes water rapidly, and that from the quadruple series excites a large electro-magnet powerfully.

1248.

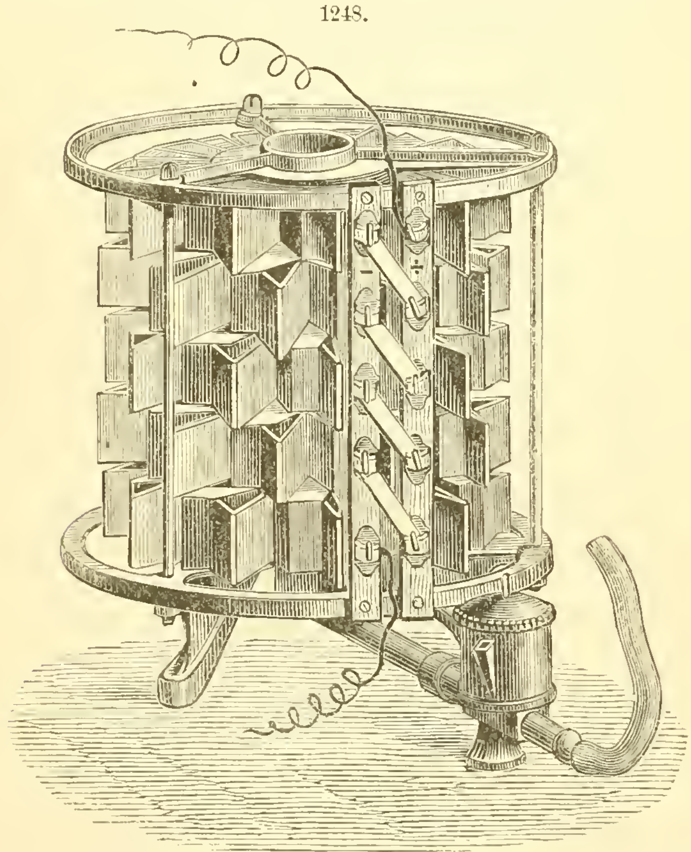


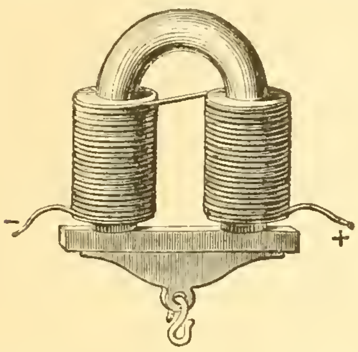
Fig. 1248 represents a small *Clamond's Pile*, connected for intensity. Iron plates are bent back on themselves irregularly, so as to present many reëntering angles. These are made to envelop the bar, so that, as the latter heats, it expands more than the surrounding metal, and so forces itself lightly into the angles. The couples are made of an alloy of zinc and antimony. The bars of alloy are assembled in crowns, which are each composed of ten bars, superposed and separated by collars of asbestos. The apparatus forms a cylinder, the interior of which is lined with asbestos, and heated by means of a perforated pipe of refractory clay. The gas burns in the annular space between the tube and bars. The consumption of gas is said to be 1 cubic foot for each volt of tension per hour. The electromotive force of this combination is such that 20 elements are about equal to 1 Daniell cell—about 1 volt.

ELECTRO-MAGNET. *Construction.*—An electro-magnet is formed by wrapping about a core of soft iron numerous turns of moderately thick and well-insulated copper wire. The core is generally bent in the form of a horse-shoe, as shown in Fig. 1249. It is frequently made by screwing the ends of two soft-iron cylinders to a stout flat iron. It must be formed of very pure iron, and be made perfectly stout by the most careful annealing after the bending (if it is bent) has taken place. It is polished with a file, and care should be taken to avoid twisting it. If this be not done, the bar retains a portion of its magnetism after the current ceases. The wire is insulated with silk or cotton, and is coiled chiefly about the two extremities, in such a way that to an observer looking upon

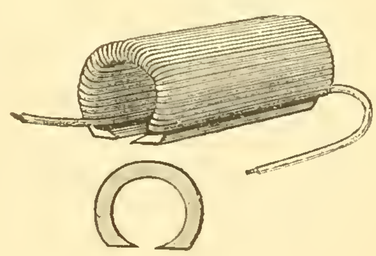
the poles it appears to be wound in opposite directions upon them. On sending a current through the coil, the core becomes instantaneously a magnet; and on breaking contact with the battery, it loses its magnetism at once. The power of the electro-magnet is enormously greater than that of any permanent magnet. A permanent magnet weighing 1 lb. has been made to carry 27 lbs.; but Dr. Joule has constructed a small electro-magnet, by arranging the coils to advantage and proportioning the wire of the core and the thickness and length of the wire, which will carry 3,500 times its own weight.

Fig. 1250 represents a simple electro-magnet which may be made of a piece of wrought-iron pipe 3 inches long by 1 inch in diameter. File away one side until through, and then, after softening it in fire, wind with cotton-covered wire in the direction of its length. It is superior to the ordinary form of magnet in its great power, arising from several causes. The poles are close to one anoth-

1249.




1250.

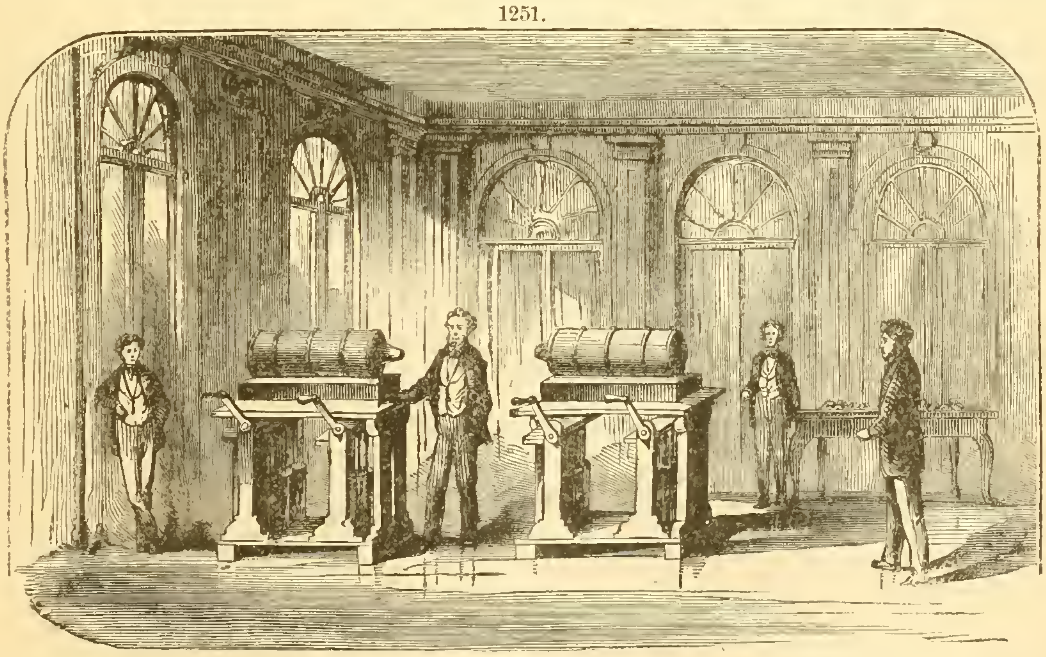


er and have large surfaces, and, from their proximity, the part of the wire in the interior of the tube reacts on both poles, thus utilizing the battery power to the full.

An electro-magnet has been made by Mr. John Faulkner which is constructed in the ordinary way, with the addition of an exterior tube of soft iron of the same length as that portion of the interior bar which projects beyond the plate. This tube has flat ends, so that a plate or keep placed over the end is in contact with both the bar and the cylinder. When excited, the magnet has a very limited field, the same being confined to the space in front of the open end of the tube, and it is said to retain its keep with 100 times more power when the outer tube is on than when it is removed. The ratio of these retaining powers seems to depend on the relative diameters of the bar and the tube; the larger the bar in proportion to the tube, the greater is the difference. (See *Telegraphic Journal*, iv., 27.)

An electro-magnet has been devised by Sr. J. S. Camacho of Havana, Cuba, in which each limb is formed of 4 hollow concentric iron cylinders, the inner one 13 millimetres in thickness, and the three remaining 7. The interior diameters of the tubes are respectively 48, 76, 106, and 127 mm. Each of them is surrounded by a coil of copper wire, covered with cotton, and of 3 square mm. in section, forming on the three inner tubes 2 complete layers with 180 turns, and on the outer tube 7 layers with 630 turns. The copper wire on each tube is coiled in the same direction, passing at its

1251.



ends across the armature of the magnet, and uniting them therefore in the natural order so as to form a single conductor, through which the current from the battery may travel, magnetizing each tube and endowing them all with magnetism of an equal nature. The length of the limbs of the magnet is 212 mm., the weight 35 kilos, and that of the copper wire 19 kilos, with a total length of 800 metres. Repeated experiments (see *Revista de Telégrafos*, No. 18, September 15, 1874) have

shown that this magnet requires the current produced by 7 bichromate-of-potash elements, and its power of attraction at a distance of 2 mm. is more than 552 kilos. An electro-magnet of the ordinary construction, of equal exterior diameter, and placed in the same conditions, supports only 11 kilos, or a weight 50 times less.

The largest electro-magnet yet constructed (1879) is in the possession of the Stevens Institute of Technology, Hoboken, N. J. Its weight is about 1,600 lbs. Some 2,000 feet of copper wire is wound on 8 brass spools, each 9½ inches high by 11¼ inches external diameter. The wire weighs 400 lbs., and is half an inch thick. The spools are split and filled in with vulcanite. The cores are hollow, and measure 6 inches in diameter by 3 feet 3 inches in length. The lifting force of this magnet is in the neighborhood of 40 tons. A good idea of its comparative size can be obtained from Fig. 1251.

*Laws of Electro-Magnetism.*—1. *The Armature.* The attraction between an electro-magnet and its armature increases with the size of the armature. 2. *The Wire.* When the current is of equal strength, the material and the thickness of the wire of an electro-magnet are without influence upon its magnetism. The free magnetism is directly proportional to the number of turns. The attraction is proportional to the square of the number of turns. When the currents are unequal, the magnet will attract a bar of soft iron with a force proportional to the square of the product of current-strength and number of turns of the core; or another magnet, with a force proportional to the sum of the products of the current and the number of turns on both magnets. 3. *Polarity.* The south pole is always at the end where the current from the carbon or copper of a battery enters a right-handed helix. Whatever be the nature of the helix, either right- or left-handed, if the end facing the observer has the current flowing in the direction of the hand of a watch, it is the south pole, and *vice versa.* 4. *Effect of Strength of Current.* The free magnetism of the pole-forces of an electro-magnet is proportional to the strength of current passing in the coils: between two magnets, the attraction is proportional to the square of the strength of the current. 5. *Action of an Electro-Magnetic Core on a Magnet.* A magnet (needle) in the axis of a circular current is attracted or repelled by the centre with a force proportional to the superficial current of the circle; and the force with which a magnet is attracted by the coil is proportional to the product of the strength of the current and number of turns of the coil. 6. *The Core.* The free magnetism, other things being equal, is proportional (*a*) to the square root of the diameter of the core, or (*b*) to the square root of its length. The magnetism is the same whether the core be an iron bar or a hollow iron cylinder of the same diameter.

For theoretical discussion of the laws of electro-magnetism, and also of the best form to be given to an electro-magnet, see papers on the subject by Count du Moncel in *The Telegraphic Journal*, ii., 23, 59. The construction of electro-magnets for experimental purposes is detailed in Weinhold's "Introduction to Experimental Physics," translated by Loewy, London, 1875. A good popular exposition of the subject appears in "The Forces of Nature," Guillemin, translated by Lockyer, New York and London, 1873.

ELECTRO-METALLURGY, or GALVANOPLASTY, is the art of separating metals from their chemical compounds and causing them to be deposited in their elementary condition upon surfaces in various forms by the agency of dynamic electricity. Its principal divisions are electroplating and gilding, and electrotyping. In electroplating and gilding the deposited metal is usually retained upon the surface on which it is deposited. In electrotyping it is subsequently removed from such surface, which forms a mould of which the deposit is a reverse copy.

*General Methods of depositing Metals.*—There are various methods which either have been or are still employed in depositing metals from their solutions for practical purposes, and they may be classed as follows: 1. By immersing one metal in one liquid, as, for instance, by immersing steel or iron in a slightly-acidulated solution of sulphate of copper. 2. By immersing two metals in one liquid, as by immersing the article to be coated in contact with zinc or other sufficiently positive metal in the particular metallic solution. 3. By immersing one metal in two liquids, as, for instance, if a deep glass vessel be half filled with a saturated aqueous solution of cupric sulphate, the vessel be then nearly filled with water containing a small quantity of sulphuric acid, poured in quietly so as not to mix with the copper solution, and a bright rod of copper, as deep as the vessel, be allowed to remain in a vertical position in the liquid during 24 hours without disturbance; the upper half of the rod will slowly corrode and dissolve, while the lower half will receive a deposit of copper. 4. By immersing two metals in two liquids, as in the ordinary "single-cell" electrotype apparatus. 5. By the separate current plan, as when a voltaic battery, magneto-machine, or thermo-electric pile is employed with a separate depositing vessel. In the present article we have to do only with the last two methods.

There are two principal forms of electro-metallurgical apparatus, respectively known as simple and compound. In the former the current is produced in the same vessel as that in which the metallic deposit is effected. It is most frequently employed when the article to be coated is small, and when time is no object. The single-cell apparatus is illustrated in Figs. 1252 and 1253. The vessel is half filled with a solution of sulphate of copper, *S*; in this is placed the earthen vessel *P*, with the dilute acid *A* and zinc *Z*, and this constitutes the whole of the present form of apparatus; for, when we desire to make an electro-medallion, it is only necessary to place one or more casts in the outer vessel *m m* connected by a wire with the zinc, and then action will immediately commence. Any number of moulds may be placed in the outer vessel, provided they can radiate to the zinc. Saturation of the liquid may be preserved by suspending some of the salt in a linen bag over the mould. This form is objectionable, because the salt of zinc speedily passes through to the outer vessel; but it has the advantage of allowing the mould to be placed vertically, in which position it is much less liable to have particles of dust settling upon it. There is no limit to the size of this outer vessel; for a water-butt, a tank, or even a lake naturally impregnated with sulphate of copper, would answer.

There is another form, where bladder takes the place of the earthen vessel, and where the position of the cast is horizontal. Here, the outer vessel, Fig. 1253, which is square, is made of wood, coated internally with cement; on one part of the edge of this a piece of brass *b* is fixed, in which are two holes, one for connection with the wire of the cast *m*, the other with that of the zinc. In the interior of the trough a movable shelf of mahogany is placed, on which is supported a glass containing a zinc plate *Z* and crystals of sulphate of copper to be dissolved. The glass has a piece of bladder tied over the rim, and this forms an outer vessel similar to the porous tube in the former apparatus. It, in like manner, contains the acid and zinc; the latter being connected by a screw to a wire, in such a way that it can be readily removed.

In every single-cell apparatus, the solution of metallic salt should be maintained in the required degree of concentration, by keeping some crystals of the salt undissolved in the solution. If these crystals are allowed to sink to the bottom of the vessel, they will not answer the intended purpose of maintaining a saturated solution; for the portions of the fluid which have been deprived of their metallic salt rise to the surface, while the saturated parts remain in contact with the crystals at the bottom, thus preventing their solution. This difficulty may, however, be readily overcome by placing the crystals to be dissolved in a little bag on a shelf at the top of the liquid, by which means the saturation of the fluid will be insured.

An excellent single-cell apparatus having a permanent battery, especially adapted for gold- and silver-plating, is represented in Fig. 1254. The exterior jar is of earthenware, the inside one of glass, with a bottom formed of bladder and fastened on with cement. Projecting into the earthen jar through the bottom is a copper rod *A*, attached to a copper plate upon which rests an amalgamated zinc plate. The lower end of the copper rod is immersed in mercury contained in the box or

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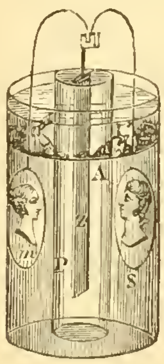
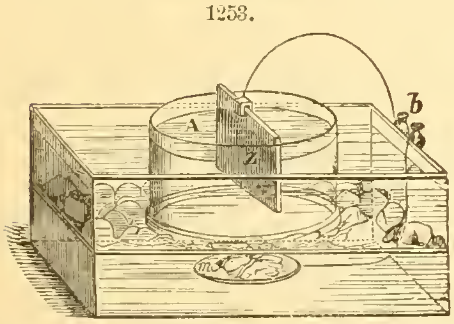



1253.

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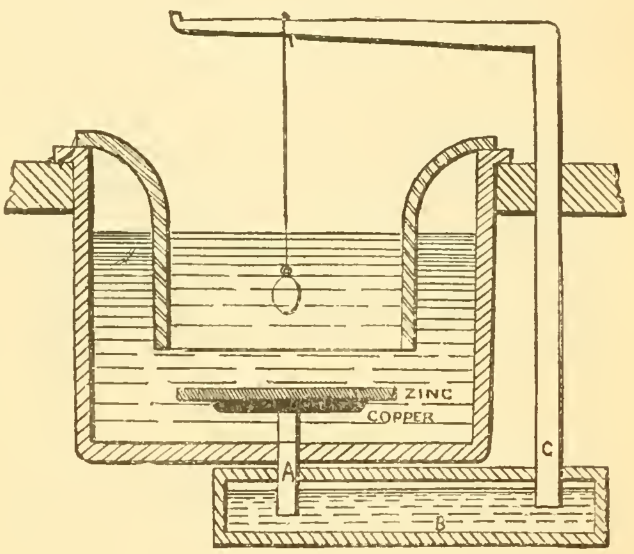


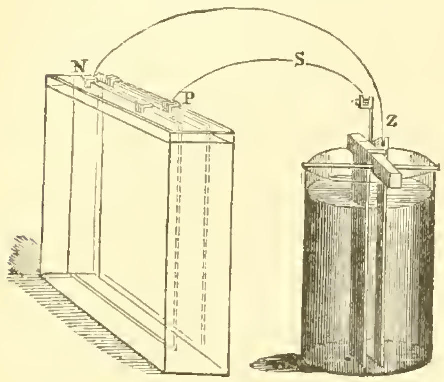

trough *B*. The lower end of the copper rod *C* also enters the mercury, while its upper extremity is bent over to sustain the articles to be plated. The battery is set in an ordinary wooden bench, so that no part is exposed save the inner surface of the interior jar. The battery is always ready for use, and, there being no acid, it is free from smell. It is unaffected by the weather, and is stated to be capable of plating in from 3 to 5 minutes. The inner jar contains the cyanide, the outer the salt solution.

Electro-metallurgical apparatus is termed compound when the galvanic current is produced outside the bath containing the solution to be decomposed. This is shown in Fig. 1255. The object *N*, on which precipitation is to take place, is connected with the zinc of the battery *Z*, while a piece of sheet copper is attached to the copper *S*. Some authorities employ the terms simple and compound with reference to the bath, according as the latter consists of one or many cells. Thus, Fig. 1255 would be designated as a simple-bath apparatus, and that illustrated in Fig. 1256 as a compound-cell bath. In the latter case the bath is divided into separate cells like those of a trough battery, the negative cell in one plate being connected to the adjoining positive plate in the next. This arrangement requires the addition of electromotive force to the battery, and is moreover found not to be so manageable or economical as the simple-cell system. It is important in this apparatus that every positive and negative plate should possess nearly the same surface, and the solution the same strength, in order that the metal of the same quality should be reduced in each cell.

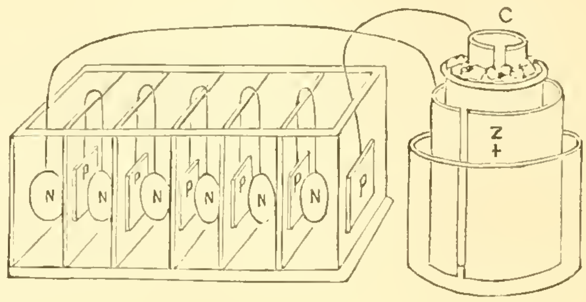
*Batteries.*—The batteries most used in electro-deposition are the old Wollaston battery of zinc and copper plates in dilute sulphuric acid, Smee's, Daniell's, Bunsen's, and Grove's. (See ELECTRO-GALVANIC BATTERIES.) Wollaston's is the most suitable one where the resistance is not great, and where a large quantity of electricity and long-continued action (as in depositing copper and silver) are required, because its electromotive force is small, its action (after once it has commenced) is toler-

ably uniform, and large plates and considerable bulks of exciting liquid may be conveniently employed. Smee's is suitable for similar cases, but where only a small quantity of electricity is required, because large plates of platinized silver are expensive. Adam's modification of Smee's battery is reliable and good, as it gives a full current and uniform action until nearly exhausted of acid. It

1255.

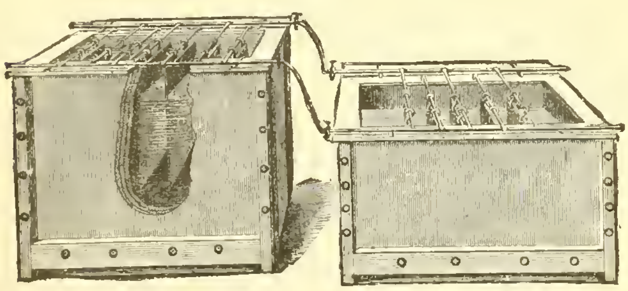



1256.




contains zinc and Smee's platinized platina plates, extending to about one-third the depth of the vessel. Platinized platina or silver plates, though expensive at first, are cheapest in the end, and work better in the battery. They are not so liable to get foul as the silver-plated and platinized copper plates, and are much more easily cleaned. The battery solution is made by pouring into the battery trough from 16 to 20 quarts of water and then 1 quart of sulphuric acid, stirring well with a piece of clean board. In Fig. 1257 is represented the construction of an improved battery of this type made by Messrs. R. Hoe & Co. of New York. It is lined with thick glass, united at the joints; and leakage is guarded against by cement and a filling of an insoluble hydrocarbon substance. Daniell's battery is the best in cases where the resistance is greater, and a very uniform current is necessary. Grove's and Bunsen's are the most suitable where the resistance is still greater, and an occasional current of considerable electromotive force, but not of long continuance, is necessary, as in gilding, and preparing for gilding (i. e., brassing or coppering) small articles of iron, steel, etc., in cyanide solutions. In all these batteries the zinc element is immersed in dilute sulphuric acid. The strength employed of this mixture varies from 1 measure of acid and 50 of water to 1 of acid and 5 of water; the usual strength with batteries such as Grove's and Bunsen's (which are soon exhausted) is 1 to 5; but with Daniell's, Smee's, or Wollaston's, 1 to 10 or 20 is a very good proportion.

1257.

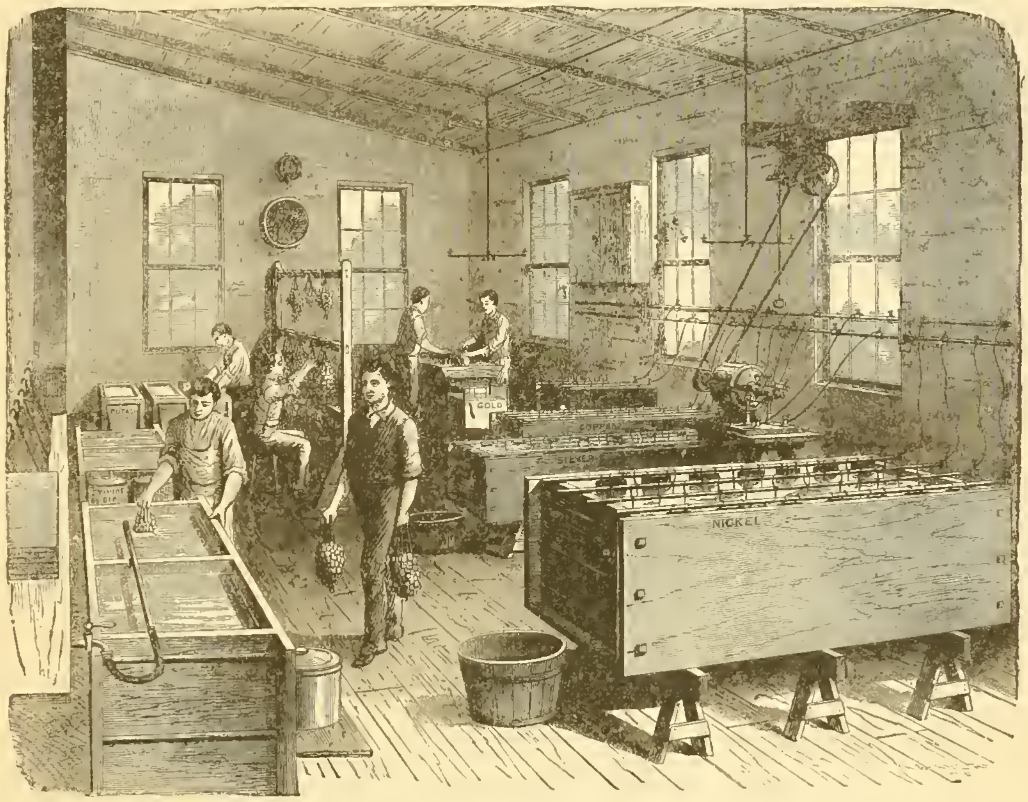


Thermo-electric piles are also sometimes used for electro-deposition. It is stated that a Clamond battery (see Electro-Galvanic Batteries), which consumes 150 litres of gas per hour, is capable of depositing 1 kilogramme of copper at a cost of 50 cents. (*Telegraphic Journal*, vol. iii., pp. 157 and 319.)

Magneto-electric machines are also largely used for the production of current for electro-deposition. Descriptions of these machines will be found under Dynamo-Electric Machines. A large Wilde machine, driven at a speed of about 2,000 revolutions per minute, has caused the deposition of 28 ounces of silver in an hour with an expenditure of 2 horse-power. A single multiple-armature machine of Wilde's (see *Philosophical Magazine*, June, 1873) has deposited 4½ cwt. of copper in 24 hours. By the Gramme machine, to deposit 600 grammes of silver requires 1 horse-power and a speed of 300 turns per minute; the tension of the current being equal to that of 2 Bunsen's cells, and its quantity equal to 32 such cells of ordinary size. At a speed of 275 revolutions per minute, it has deposited 525 grammes of silver per hour; at 300 revolutions, 605 grammes; and at 325 turns, 675 grammes. The weight of the copper wire on the fixed electro-magnets was 135, and on the movable ones 40 kilogrammes. (*Telegraphic Journal*, vol. i., p. 54.) An improved form of magneto-electric machine by Siemens and Alteneck will be found described in the *Electrical News*, vol. i., p. 226. The chief obstacle to the use of these machines is that, after a few hours' action, the different parts are liable to become considerably heated, partly by the incessant molecular changes attending the variations of magnetism, and partly by the conduction-resistance of the coils. This has been largely overcome in Wilde's machine by the employment of several small machines instead of one large one, and by allowing a stream of cold water to run through the hollow ends of the magnet. In Gramme's machine, provided it is not worked too fast, the heat is reduced to a moderate amount. Another common objection is the complexity of the commutator. The Weston machine, for the construction of which see Dynamo-Electric Machines, has been used for electroplating with much success, it being claimed that a shell can be obtained by the machine in from 2 to 2½ hours, equal to that from the usual batteries in from 10 to 12 hours. In Fig. 1258 is exhibited the interior of a large electroplating works using a machine of this class. The illustration also shows the arrangement of tanks. The machine is rotated at 800 revolutions per minute, and is connected by means of wires to rods running across the various tanks containing the metal solution to be deposited. On the tanks

are rods supporting the anodes or metals to be deposited, and also the work to be plated. It is usual to place the tank containing the nickel solution nearest the machine, as this solution offers the greatest resistance to the electrical current. A solution of cyanide of copper is used in many cases as an intermediate deposit upon iron or steel before the nickel, as it prevents the tendency to rust

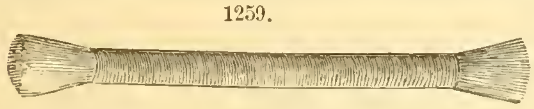
1258.



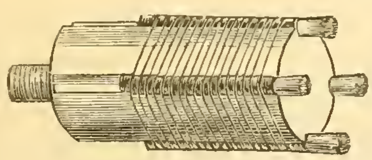

upon exposure. This solution is also used for depositing copper on zinc and lead, or articles made up of several metals.

*Preparatory Cleansing.*—All articles which are to receive a deposit require to be made scrupulously clean. The surface should also be rendered smooth by means of the revolving "scratch-brush," and by other methods. Articles of copper are usually not scratch-brushed, but dipped.

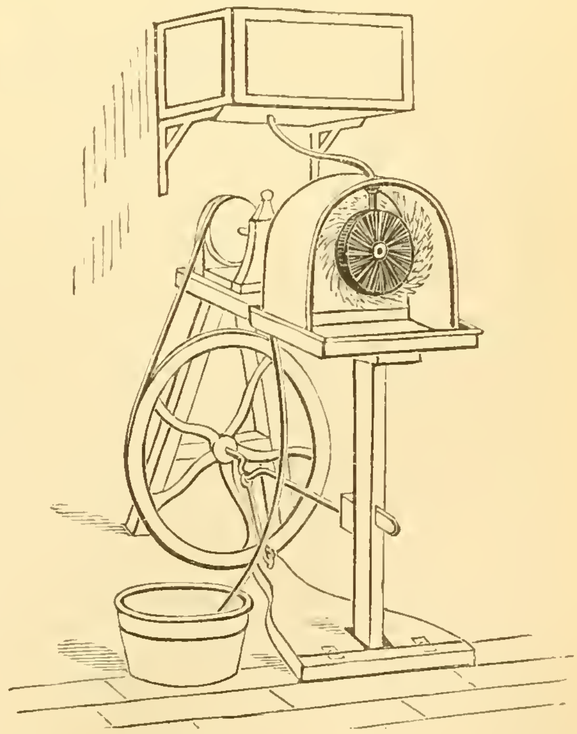
1259.



1260.



1261.



The processes of cleansing are both of mechanical and chemical nature. The mechanical means are the usual ones of filing, scrubbing, and scouring with various gritty materials. Emery-cloth is employed when the articles are dry, and fine silver-sand and a hand-brush, or piece of canvas, when they are wet. In addition to this, an instrument called a scratch-brush is continually used, and cannot be dispensed with. A scratch-brush is merely a bundle of fine and hard brass wires, about 6 or 8 inches long, bound round very tightly with other wire except at the ends, Fig. 1259. These wires are of various degrees of fineness, and are also annealed to different degrees, to suit the various kinds of work. Four of such brushes are usually fixed in grooves upon the outside of the chuck of a lathe, so that the wires are parallel with the axis of the chuck (see Fig. 1260). Another form of scratch-brush, in which the wires are radial instead of parallel, is shown in Fig. 1261. To use these brushes, a lathe is required. A "scratch-brush lathe," suitable for cleaning small articles, is represented in Fig. 1261. Above the revolving brush is placed a cis-

tern containing stale beer, a little of which is allowed to dribble upon the articles during the process of brushing, and the brushes are surrounded by a screen to prevent splashing.

The chemical methods of cleaning consist in immersing the articles, for a greater or less period of time, in various acids or alkalies, according to the nature of the metals. Alkalies are usually employed hot, and are generally used for removing greasy, tarry, or resinous matters; and acids are generally used cold, after the greasy matters have been removed. The alkalies are kept in iron vessels, and the acids in stoneware pans, etc.

The alkali commonly employed is caustic potash. Several kinds of acid liquids are used, viz., dilute sulphuric, strong nitric, and various mixtures of them. All greasy articles are always dipped in potash solution, and then "swilled" in water. Those of lead, tin, Britannia metal, pewter, and zinc are similarly treated. Iron is cleansed in strongly diluted sulphuric acid. Silver is dipped in dilute boiling sulphuric acid. Articles of copper, brass, or German silver require a series of liquids, consisting, first, of strong nitric acid; second, a dipping liquid composed of water 64 parts, sulphuric acid 64 parts, nitric acid 32 parts, and hydrochloric acid 1 part; and third, spent liquid, i. e., either nitric acid, or dipping liquid which has become weak. Many articles which are to receive deposits require to have portions of their surface "stopped off," to prevent the deposits spreading over those parts. For gilding and other hot solutions, copal varnish is used; for cold liquids, an ordinary varnish will answer. "Quicking" means coating the surfaces with a film of mercury, for the purpose of causing the deposited metal to adhere firmly. Solutions of cyanide of mercury are used for preparing the surfaces of copper, brass, and German silver for receiving silver deposits.

Electroplating.—The following practical directions for the deposition of the different metals are mainly taken from Gore's "Electro-Metallurgy" (New York, 1877), to which the reader is referred for further details.

*Antimony.*—In depositing antimony by the battery process, the metal may be obtained not only in a state of loose black powder, but also in two distinctly different, coherent, reguline conditions, viz., as a very brittle metal of a gray-slate color and hard crystalline structure, and also as a highly lustrous steel-black deposit, of amorphous structure, and somewhat less hard than the pure variety, which retains its color and brightness without oxidizing for a long time. A satisfactory solution for obtaining the pure gray metal is composed of distilled water 12 ounces, tartar-emetic 1 ounce, tartaric acid 1 ounce, pure hydrochloric acid 1½ ounce. It is not a good conductor, and should be worked slowly, with two Smee's elements, at such a rate as to deposit about one-eighth of an inch thick of metal in four weeks.

*Bismuth.*—According to M. A. Bertrand, metallic bismuth may be deposited upon copper or brass from a solution composed of 30 grains (grammes?) of the double chloride of bismuth and ammonium, dissolved in a litre of water slightly acidified with hydrochloric acid, by means of a current from a single Bunsen's cell. He states that antimony may be deposited in a similar manner (*Athenæum*, April 22, 1876, p. 570), and recommends its use for artistic decorations, instead of platinum-black.

*Brass.*—A good solution for brassing by means of a separate current, with an anode of brass, may be made by dissolving 9 or 10 ounces of the strongest aqueous ammonia, and 16 to 20 of cyanide of potassium (with or without the addition of 20 of the strongest aqueous hydrocyanic acid, "Scheele's strength"), in 160 (i. e., 1 gallon) of water, and saturating the hot liquid with brass by means of an electric current; it must be used at 212° F.

*Cobalt.*—To deposit the metal, dissolve 5 ounces of the dry chloride in a gallon of distilled water, and make the solution slightly alkaline with ammonia. Pass the current through the liquid, either by using a plate of cobalt as anode, or a bar of gas-carbon in contact with a heap of fragments of cobalt contained in a gutta-percha basket. From 2 to 5 Smee's cells are required. The solution must be kept slightly alkaline.

*Copper Deposition by Separate-Current Process.*—In depositing copper by the single-cell method, a nearly saturated solution of sulphate of copper answers very well; but for the battery process, an excellent solution may be made by dissolving 4 parts by weight of finely-powdered sulphate of copper (best quality), and 1 of sulphuric acid, in about 18 or 20 of water, and then filteing it. Neither of these solutions, however, is fit to deposit copper upon steel, iron, or zinc, because the electrical relations are unsuitable; these metals decompose such liquids rapidly, and deposit the copper upon themselves by simple immersion. Some persons use a solution containing a smaller proportion of acid, a greater one of copper salt, and less water; and others add a small quantity of sulphate of zinc or sulphate of potassium to the liquid; the latter is very good. The sulphate solution is used for coating all metals and alloys, such as brass and German silver, which do not decompose that liquid; but zinc, iron, steel, tin, lead, Britannia-metal, type-metal, etc., which precipitate the copper from such a liquid by simple immersion, are coated in the cyanide or other alkaline solution; and as the deposition of copper from an alkaline liquid is more expensive than that from the sulphate, if a greater thickness of metal is required, the additional thickness is put on the articles in the sulphate solution. A very good solution may be formed thus: Dissolve cyanide of copper to saturation in water containing about 2 lbs. of cyanide of potassium to the gallon, and then add about 4 ounces more of the potassic salt per gallon, to form free cyanide; the liquid is then ready, and should be used at a temperature of about 150° F. Cyanide of copper is not very soluble in cyanide of potassium solution; the liquid formed does not readily dissolve the anode, nor does it conduct well; it also has a strong tendency to evolve hydrogen at the cathode, but this may be lessened, or wholly prevented, by avoiding the use of any free cyanide of potassium, employing a weaker current, and adding some aqueous ammonia and oxide of copper. Busts and other similar objects may be coated with copper by saturating them with linseed-oil (or better, with beeswax), then well blackleading, or treating them with the phosphorus, silver, and gold solutions, attaching a number of "guiding-wires," connected with all the most hollow and distant parts, and then immersing them in the sulphate of copper solution, and causing just sufficient copper to be deposited upon them by the battery process

to protect them, but not to obliterate the fine lines or features. Further particulars relative to the deposition of copper will be found under the section on electrotyping.

*Gold.*—The electric current employed is usually derived either from a Bunsen's battery or a Clamond's thermo-electric pile, that from a magneto-electric machine being found to be less suitable. Many solutions have been tried, but none have succeeded like the double cyanide of gold and potassium. They may be formed either by chemical methods or by means of the battery process. The latter is preferable, as it is unattended by the risk of loss of metal, which occurs in the chemical process. To prepare a cyanide gilding solution by this plan, simply dissolve some cyanide of potassium in hot distilled water, in an earthenware vessel, in the proportion of from 1 to 2 lbs. to each gallon. Immerse 2 large electrodes of pure sheet gold in the liquid, and pass the current from about 3 Smee's or 2 Daniell's cells, stirring the liquid occasionally, until a clean and bright cathode of German silver (substituted a short time for the gold one) receives a proper coating. The liquid should be kept at a temperature of about 150° F. during the process, by immersing the vessel containing it in an outer vessel of hot water with a lamp beneath. The quantity of gold dissolved from the anode is ascertained by weighing, and is not of material consequence, provided the deposit is good. In this process a portion of the cyanogen from the cyanide unites with the gold, and leaves potash in the solution, and after a time, being exposed to the atmosphere, absorbs carbonic acid, and thus brings carbonate of potassium into the liquid; but the presence of this salt is not objectionable. A very good gilding solution made by this method consisted of 1 gallon of water, 1½ lb. of cyanide of potassium, and 50 pennyweights of gold.

*Nickel.*—The bath may be composed either of the chloride of nickel and ammonia or the corresponding sulphate, dissolved in pure water. If the latter is used, the solution must be kept neutral and up to about 6° of hydrometer. It is prepared by dissolving three-fourths of a pound of the salt in each gallon of water. This salt is generally considered the best for nickel-plating, and costs $1.30 a pound (1879). From this bath the nickel can be profitably deposited at $2 a pound. The chloride bath requires about 4 ounces of the salt per gallon, and works better with a slight acid reaction, the tendency in working being toward alkalinity, even with great exposure of anode. The intensity of battery current must be proportioned to the bath, and remain constant. Large baths offer less resistance to the electric current than those of smaller dimensions, and can therefore be worked with a current of somewhat less tension. For a bath of 10 gallons or less, the tension of the current should be equal to that of from 2 to 3 Smee cells (carbon and zinc) in series. The exposed surface of the nickel anodes should in no case be less than the surface to be coated, but may with advantage be greater. The amount of battery power for a given amount of work should be in zinc surface equal to the surface to be coated, with care to preserve the normal tension of the current. If the current is too intense, the coating will present a dull white or frosted appearance. The anodes must be in connection with the negative plate (carbon) of the battery. Damage is not infrequently done to the bath and work by misconnection. The work should be scrupulously clean when entered to the bath, and should be carefully moved about after entering to free it from any adhering air-bubbles. If the finished work is to have a smooth polishing surface, it must present such a surface before entering the bath. Nickel is hard, and cannot well be burnished. Traces of oil and grease are removed by a hot soda solution. After dipping in clean water, the surface is freed from films of oxide by an acid bath. If the work is of iron, the acid may be hydrochloric diluted with 3 or 4 volumes of water; if of copper or brass, nitric acid diluted with about 20 parts of water. Brighten the work in the acid dip, then immerse momentarily in water; go over it with a clean stiff brush and very fine sand; again dip in the acid, then quickly in soft water, and place immediately in circuit. The hand must not come in contact with the surface of the work after removal from the alkali, as the slightest touch may spoil all. On removal of the work from the plating bath, it should be immediately dipped in cold water and transferred to hot water, which will cause it when taken out to dry quickly and perfectly. The bath should be covered when not in use, to keep out dust and prevent as much as possible its evaporation. By a little practice and proper attention to these simple rules, the nickel bath may be worked continuously, month after month, and the metal deposited smoothly and with certainty.

*Silver.*—The following solutions for plating by a separate current may be made either by chemical means or by the aid of an electric current. The best solution for general purposes is the double cyanide of silver and potassium, and when required in large quantities it is usually made by chemical means. Many solutions have been proposed and tried for depositing silver by the battery process, but none have stood the test of time and experience like the one composed of double cyanide of silver and potassium dissolved in water, and a little free cyanide of potassium added. It must, however, always be remembered, when making cyanide depositing solutions with the aid of potassic cyanide, that the composition of this salt, as usually sold, is extremely variable; and unless the depositor is aware of this, he may be led quite astray in his calculations, and unwittingly introduce various impurities into his depositing liquids.

The ordinary cyanide of silver-plating solution is best made by the battery process. To make by this method a solution containing 1 ounce of silver per gallon, first ascertain the percentage of actual cyanide in the salt of potassium to be used. If it contains about 50 per cent., dissolve about 3 ounces of it in each gallon (=160 ounces) of distilled water; or if it contains more, add less, and if less, add more, in proportion. Suspend a large anode and a small cathode of silver in the liquid, and pass a strong current of electricity, until about 1 ounce of silver for each gallon of liquid has dissolved from the anode, or until, with a moderate current, and electrodes of average size, a bright silver or other suitable cathode receives a good deposit. As this process produces some caustic potash in the liquid, some of the strongest hydrocyanic acid may now be added to form cyanide, and some more silver then dissolved in the mixture by the battery process.

The following is an outline of the French method of silver-plating: Immerse the articles of cop-

per, brass, or German silver, during a few minutes, in a boiling solution of 1 part of caustic potash in 10 parts of water. Swill them thoroughly in clean water. Dip them into a liquid composed of 10 parts of water and 1 of sulphuric acid. Rinse them again. Immerse them during a few seconds in a mixture of 20 parts of common salt, 20 of calcined soot, and 1,000 of yellow nitric acid of specific gravity 1.332, and swill them as quickly as possible in plenty of water. Dip them also rapidly in a mixture (prepared some time beforehand) of 1 part of sulphuric acid, specific gravity 1.846, 40 of common salt, and 1,000 of yellow nitric acid, of specific gravity 1.332, and instantly wash them well in clean water. Dip them at once for a few seconds, or until they are quite white, in a "quicking" solution composed of 10 parts of nitrate of binoxide of mercury and 1,000 parts of water containing sufficient sulphuric acid to make the solution clear, and swill them again in the fresh water. Immerse them in the plating liquid, using a weak current; and if the deposit looks good, continue the process; but if it looks uneven or spotted, take them out, "scratch-brush" them, dip them into a hot solution of cyanide of potassium, and then in fresh water; "quick" them afresh, rinse them again, and then continue the process. When the plating is finished, stop the current a few minutes before removing the articles, in order to remove subsalts of silver from the deposit, and prevent its turning yellow. Swill them in water, then in water slightly acidified by sulphuric acid, again finally in water, scratch-brush them if necessary, swill them again, dry them in hot sawdust of boxwood, and weigh them.

The rapidity with which metal of good quality can be deposited depends largely upon the composition of the solution. To work rapidly, the solution should contain a rather large proportion of free cyanide of potassium; otherwise, the anode becomes covered with an insoluble film before free cyanide from the articles can diffuse to it, and this film impedes the current. In a good silver solution, a dozen of ordinary table-spoons or forks will acquire 1,000 to 1,500 grains of silver in 12 hours; but there are solutions used in Birmingham, in which it is said as much as 1 ounce of silver can be deposited upon a small table-spoon in half a day. Electroplated articles vary greatly in quality, because any degree of thinness of silver may be put upon them. Great quantities of Britannia-metal articles are coated with only a few pennyweights of silver per square foot. "The thickness of electro-deposited silver is in many cases from $\frac{1}{42}$ to $\frac{1}{450}$, or even $\frac{1}{9400}$ of a millimetre, or 1.24 grain upon a square metre of surface." One ounce of silver per square foot of surface is equal to a coating of about the thickness of thin writing-paper, and is considered an excellent coating.

*Tin.*—There are many solutions for electro-tinning by means of a separate current, but only a very few have been extensively used. Most of them alter in property by contact with the atmosphere, and deposit their metal as a white oxide. Roseleur uses a solution composed of 5 parts of fused (or 6 of crystals) stannous chloride, and 50 of pyrophosphate of potassium or sodium, added to 5,000 of distilled water; the chloride is dissolved in a portion of the water, and added the last, and the liquid is stirred until it is clear. A very large surface of anode is employed, and a strong electric current. As less tin is dissolved than is deposited, it is necessary to add occasionally equal weights of the pyrophosphate and fused chloride.

*Zinc.*—Zinc may be deposited from its sulphate, ammonio-sulphate, chloride, ammonio-chloride, acetate, tartrate, etc., by the separate-current process. As with nearly all other metals, the nitrate forms a bad depositing solution. By proper management, good coherent metal may be obtained from the sulphate, acetate, and chloride. A solution of zinc in caustic potash is not a good conductor; a zinc anode does not readily dissolve in it; similarly with the potassio-tartrate and potassio-cyanide (Smee). A solution of 1 part of the sulphate in 5 to 10 parts of water, with a large zinc anode, may be made to yield a good deposit, by a current from two small Smee's cells feebly charged.

Many years ago, sheets and other articles of iron were coated with zinc by electrolysis, in order to protect them from rusting; but this process has been entirely superseded by the so-called "galvanizing," which is not a galvanic process at all, but consists of dipping the previously cleaned iron into a bath of melted zinc; the latter being covered with a layer of saline flux, in order to prevent oxidation, and also to dissolve any trace of oxide which may be upon the iron articles. Such a coating of zinc is a much more effectual preventive of rusting than an electro-deposited one, because the heat expels all moisture from the pores of the iron, and the layer of zinc is homogeneous, and not granular or porous, while that formed by voltaic action is always more or less porous, and very liable to contain traces of the depositing liquid; the surface beneath the electro-deposit, not having been heated before receiving the coating, is also liable to contain moisture and acid, absorbed during the preparatory processes of cleaning, etc.

*Wright's Hot-Vapor Electroplating.*—A method of electroplating has been discovered by Prof. A. W. Wright, which consists in plating the surfaces of substances with metals by exposing such surfaces to the hot vapors of whatever metal it is desired to plate with. The metal is volatilized by the electric current. The apparatus consists of a hollow vessel, from which the air is partially exhausted; within this vessel are arranged opposite to each other the two poles of an induction coil. The article to be electroplated, a bit of glass for example, is suspended between the poles; to the negative pole is attached a small piece of the metal that is to be deposited on the glass. Grove cells of 3 to 6 pints are employed, yielding, by means of the induction coil, an electrical spark from 2 to 3 inches in length. Under the influence of this spark a portion of the metal of the electrode is converted into gas, or volatilized, and condenses upon the cooler surface of the suspended glass, forming a most brilliant and uniform deposit. The thickness of the plating thus produced may be regulated at will, by simply continuing the action of the electricity for a longer or shorter period. That the metal is actually volatilized is proved by examination with the spectroscope during the progress of the operation, the characteristic lines of whatever metal is used for the electrode being fully revealed. (See *American Journal of Science and Arts*, vol. xiii., January, 1877, and vol. xiv., September, 1877.)

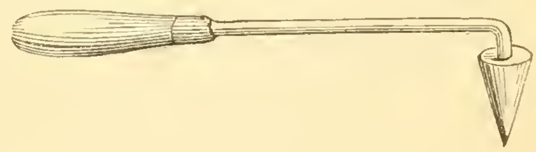
Electrotyping.—The following excellent account of the process of electrotyping, with descriptions of the most improved machinery and tools, is condensed from "Hints on Electrotyping and Stereotyping," a pamphlet issued by Messrs. R. Hoe & Co. of New York.

*Moulding.*—The type should be perfect, and set up with high spaces and quadrats and with type-high bearers all around it. This prevents the wax from spreading while the form is pressed in it, and also facilitates the operation of "backing." Forms for electrotyping must be locked up tighter than those for press-work. Great care must be taken that the form be well justified, all spaces planed down, and the surface perfectly clean. Blacklead freely with a fine, soft hatter's brush, removing the surplus. A well-leaded form facilitates the drawing of the mould, and prevents the wax from adhering to the woodcut or type. Woodcuts are locked up in the same way as type, but before blackleading they must be perfectly cleaned with naphtha or benzine from the ink which is commonly adhering to them, and dried thoroughly. Great care must be taken that no particles of black lead clog the fine lines of the engraving, as very much depends upon the preparation of the form for moulding. The cuts, of course, must be brought up to exact type height by proper underlaying.

The *moulding-case* is a flat brass pan about a quarter of an inch deep, with two flanges, which fit into the clamps of the moulding-press. The back of the pan must be planed smooth. The moulding composition is made of the best pure yellow beeswax. In a temperature of 90° to 95° the wax may need no admixture; but if the room is cooler, it should be prevented from cracking by the addition of from 5 to 20 per cent of virgin turpentine. New wax should be boiled several hours before pouring into the moulding-case; old wax, only long enough to evaporate all moisture. Care must be taken not to have too much heat, or the wax will be burned and rendered quite useless. Steam is much the best for this purpose, as with it the wax cannot be overheated. The moulding-case, having been slightly warmed, is placed on the level *case-filling table*, and the melted wax is poured into it with a clean iron or copper ladle, great care being taken to run the wax entirely over the case while it is hot, so that its cooling too quickly may not cause irregularities in any part. The air-bubbles which rise to the surface must be touched with the heated building-iron. Should the wax shrink away from the edges of the case, it can be remelted there by running the heated iron over it when it is just set. When the wax has become cool, it should present a smooth, even surface; otherwise it is useless, and it is better put back into the pot to be melted over again. The whole surface should now be carefully and thoroughly rubbed over with black lead, by means of the soft brush alluded to, after which the wax is ready for the impression. The form is placed on the bed of the press, and the moulding-case in the clamps on the head of the press, immediately over but not touching it, and the bed is raised until a proper impression is taken in the wax. The exact depth can only be attained by practice. Should the form stick in the wax, it may be relieved by touching the chase gently in two or three places with a long screw-driver, so as not to break the face of the wax. When once the form or engraving is withdrawn from the wax, it must not be reëntered, as it probably would not go exactly into the same place again, and the impression would be rough.

Now remove the case from the clamps and place it upon a table ready for the process of building. This operation requires skill and a steady hand. A well-built mould will save a great deal of trouble in the stages which follow, as the object is to obviate as much as possible the necessity of chiseling the plates. Wax is run or built on the places where blanks are to be. This building is performed with the building-iron, Fig. 1262, which is heated and applied to a strip of wax, melting it and causing it to flow down from the point of the iron on to the blanks of the mould. This process cannot be easily taught, but it must be acquired by careful practice. The great difficulty is to prevent the wax from running where it is not required. A quick eye and steady hand will do this. The wax used in building should be cut in strips of various widths to suit the work, and must be kept perfectly dry. If any portion gets damp, it is best not to use it for building purposes, as there is danger of its spattering over the mould. The building-iron must not be too hot.

1262.



After the wax mould is well built, it is ready for blackleading, which is necessary to give it a conducting surface and cause the copper to be gradually deposited over every part of it. Black lead for this purpose must be pure, with a bright lustre, free from grit, and very fine. If it is inferior and dead-looking, it is worse than useless. It must be thoroughly worked into every letter and line, or it is useless to put the mould into the precipitating cell, for the copper will not be deposited perfectly over its surface. The *black-lead machine* has a traveling carriage that holds the mould, or several moulds if small, and passes backward and forward under the vibrating brush. One 12 by 18 inches can be blackleaded in two minutes. An apron under the machine catches the powder and prevents waste. After this operation has been thoroughly performed, the superfluous black lead is removed by a broad-nosed bellows, not a particle being allowed to remain, or, the copper being deposited over it, a rough and faulty electrotype will result. The mould, held to the light, should reflect from all parts of its polished face. The black lead being an inferior conductor, and its whole surface not being in the current at once, it is necessary to have some nucleus of metal on which the copper deposit may commence. This is sometimes provided by removing the wax from the rim of the brass case, on which the deposit will begin, and from which it will gradually spread over the whole surface of the wax. Another way is to fasten a piece of metal to the wax at the top of the mould, and connect it with the metal by a copper wire, perfectly clean, wound around the connecting-rod. The back and edges of the moulding-case must be coated with hot wax after it is blackleaded, to prevent the copper forming upon it. To prevent the deposit of copper on any places where it is not wanted, the hot building-iron is run over them so as to destroy the continuity of the black-lead surface. To dispel the film of air which forms on the surface of the blackleaded wax,

before placing in the precipitating cell, lay the case in an inclined shallow tin pan, and pour alcohol over it, beginning at the upper side. Then place the case on its back in a shallow trough, and force water on it by a pump through a flexible tube, taking care that the water thoroughly penetrates the cavities and forces out the air-bubbles which adhere so tenaciously. The mould should now be taken out and quickly placed in the precipitating cell.

*The Battery.*—See that all the connections are perfect. Those from the platinized plates in the battery lead to the copper plate in the precipitating cell, and from the zinc plates to the wax mould. The copper plate must be suspended about 2 inches from the mould. The battery should not work too rapidly, or the shell will be spongy and unfit for printing. If too strong, remove some of the negative or zinc plates; if too slow, increase either zinc or platinized plates, or add sulphuric acid. Perhaps, if the battery has been running some time, only water may be needed to excite its action; but always remove both negative and zinc plates when pouring acid into the battery solution. The solution of the sulphate of zinc in the bottom of the battery should be removed as it becomes saturated by a siphon, and fresh water and acid added. If the battery is working properly, 10 or 12 hours will give a perfect shell; but if it is found that some part of the mould is not covered with copper, wash it off well with water, and with the finger or brush rub black lead upon it, after which the copper will soon run over it. This will never become necessary, however, if the wax has been sufficiently blackleaded in the first place. The strips of sheet copper forming the connection between the battery and the precipitating trough should be of sufficient width to conduct a plentiful current of electricity; in fact, it is better to have them larger than is actually required. The rods, hooks, and all connections, on both battery and precipitating trough, should be well cleaned with sand-paper.

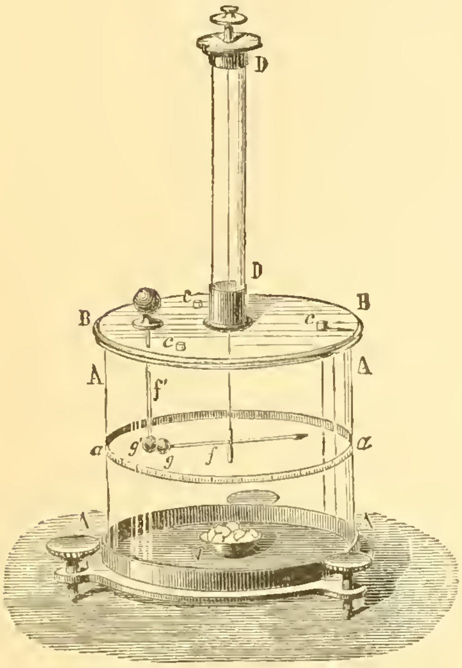
*Adams's Process for Covering Moulds with a Metallic Surface.*—This process, patented in 1870, is claimed to give a perfect surface with certainty and rapidity. While the wax is still warm in the moulding-case, apply finely powdered tin with a soft brush until the surface presents a metallic appearance. Then brush off superfluous powder. The form of type or woodcut is first coated with black lead, to insure the separation of the mould from it, and an impression is taken in the wax, after which the black lead is blown out. Build up and connect the mould in the usual manner. Then brush, by hand or machine, tin-powder over it, and, after blowing out again, touch with a hot building-iron all parts of the mould on which the copper is not to be precipitated. Immerse it in alcohol, then wash with water to remove the air from the surface, and it is ready to be suspended in a solution, which must be made as follows: Fill a precipitating cell nearly full with water, keeping an account of the number of gallons poured in; hang a bag of sulphate-of-copper crystals in the top of it until the water is saturated; for every gallon of water add from half a pint to 3 gills of sulphuric acid, and mix the whole thoroughly. In this solution hang a sheet of copper, connecting it with the negative plates of the battery; and when the solution becomes cool and settled, immerse the mould and connect it with the positive or zinc pole of the battery, when the surface of the mould will be quickly covered with thin copper. Then remove for completion to another and larger precipitating cell, containing a solution made in the proportion of one pound of sulphate of copper and one gill of sulphuric acid to each gallon of water. If sulphate-of-copper crystals form on the copper plate in the first precipitating trough, detach it and dissolve them off, adding another plate in its place. When the solution in the first precipitating cell has become nearly saturated with tin, which will happen after a long time, it should be thrown away and replaced with fresh. This process of using a metallic powder in connection with black lead, or in place of it, is said to accomplish in a few minutes what with black lead alone requires from 2 to 4 hours.

ELECTROMETERS AND GALVANOMETERS. ELECTROMETERS.—For the purpose of ascertaining the intensity with which a body is charged, and also the laws of electrical attraction, an instrument was invented by Coulomb, called Coulomb's torsion-balance electrometer, illustrated in Fig. 1263. Its essential parts consist of a fine metallic wire, which is held on a cap at the top, and supports a delicate horizontal needle of shellac. The needle has a small gilt ball $g$ at one extremity. Another rod of shellac, $f'$, is so adjusted in the cover of the large glass cylinder that the small gilt ball $g'$ may be passed down and held at a level with the latter. If, now, the horizontal needle $f$ is so placed that the ball $g$ may be touched by the ball $g'$, and the latter is charged with electricity and introduced, it will deliver to the former half of its charge, and the two will be mutually repelled, the repulsion being measured by the amount of torsion of the suspending wire, which may be ascertained by means of a circular scale marked upon the circumference of the cylinder, and another suitably adjusted at the upper end of the small cylinder, from which the wire is suspended. The cap at the top may be turned to increase the force of torsion, which is in proportion to the angle, and to bring the balls nearer together. With this instrument Coulomb demonstrated the following laws: 1. The force of attraction and repulsion between two electrified bodies is in the inverse ratio of the squares of the distance. 2. The distance remaining the same, the force of the attraction and repulsion between two electrified bodies is directly as the product of the quantities of electricity with which they are charged.

GALVANOMETERS.—It has been stated that if a magnetic needle is brought near a wire through which a galvanic current is passing, it will be deflected; the direction depending upon the relative position of the wire to the needle, and upon the direction of the current. Upon this peculiar action depends the construction of an instrument which is used for measuring the strength of a galvanic current, called a galvanometer. If the wire is held above the magnetic needle, and parallel to it, and a current is passed in the direction of its north end, that end will be deflected to the left, as represented in Fig. 1264, when the observer is looking downward and to the north. If the wire is held under the needle, and the current passed in the same direction, the north end will be deflected to the right; but if the current is passed from north to south, the needle will be deflected in the same direction as when the current passed above it from south to north. If, therefore, the wire is turned upon itself, as represented in Fig. 1265, two forces will act upon the needle, tending to deflect

it in the same direction; and if the wire is formed into a flat coil, the deflecting force exerted upon the needle will be multiplied nearly as many times as the wire passes backward and forward. Schweigger's multiplier, constructed in this manner, is shown in Fig. 1266. The sensitiveness of the instrument is increased by using what is called an astatic needle, which is constructed by placing two magnetic needles upon the same axis, but with their north and south ends in opposite directions, and suspending them horizontally by a delicate fibre of silk. If their axes are perfectly parallel, and they have precisely the same magnetic force, they will form a system which is astatic; that is, they will when acted upon only by the earth's magnetism point indifferently in any direction. It is however

1263.

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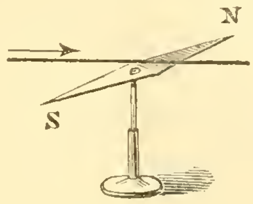


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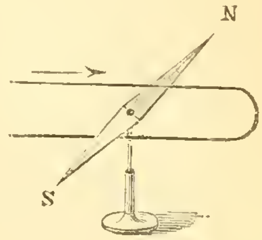


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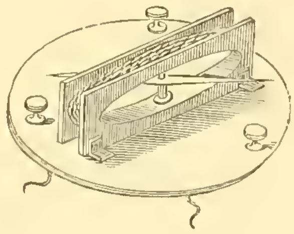
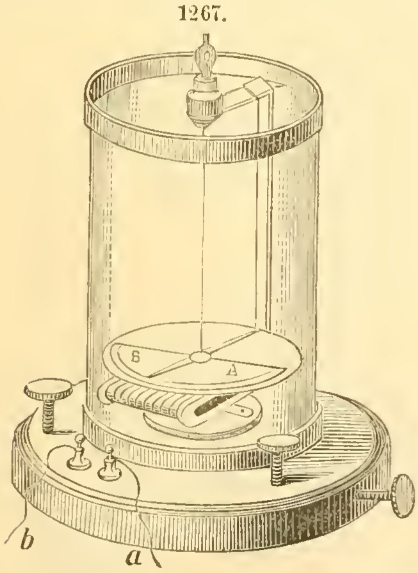


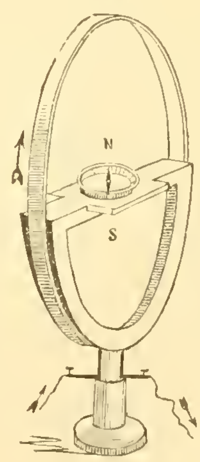
impossible to place them perfectly parallel, and it therefore follows that when they have equal magnetic force they will only come to rest when at right angles to the plane of the magnetic meridian. It is usual, however, except in the most delicate tests, to have one of the needles slightly stronger than the other, so that there shall be a slight directive tendency north and south to the system. If a wire carrying a current is held between the two needles, they will both be deflected in the same direction; and if the wire is formed into a coil, the force will be multiplied. An astatic galvanometer is represented in Fig. 1267.

The astatic galvanometer cannot be used to measure currents of much strength, on account of its

1267.




1268.

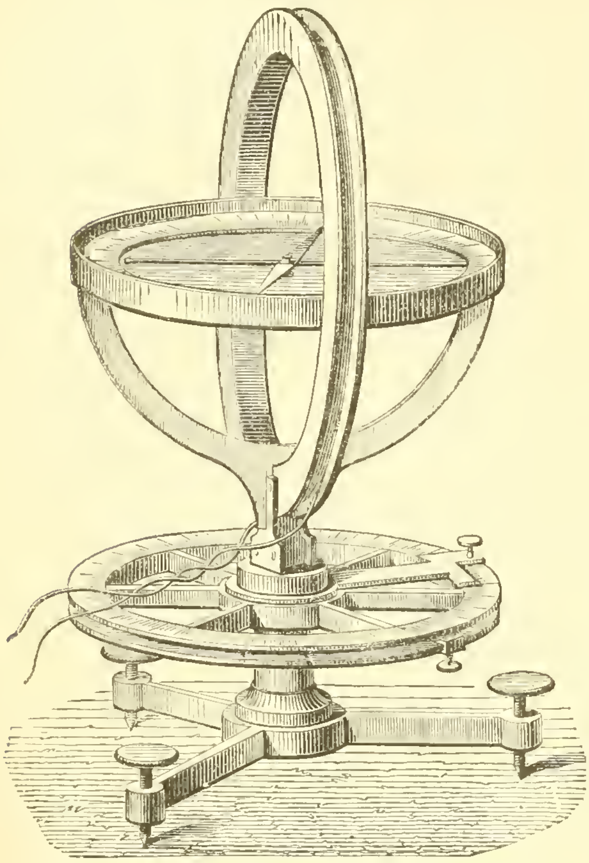



too great delicacy. For this purpose the tangent galvanometer and the sine galvanometer are employed. The tangent galvanometer, Fig. 1268, consists of a vertical circle made of a band of copper, the two ends of which are connected with the poles of a battery. In the centre of this vertical circle a small magnetic needle is placed, in length about one-twelfth of the diameter of the circle. When the needle is no longer than this, the tangent of the angle of deflection will be proportional to the strength of the current. In using the instrument, the plane of the vertical circle is placed in the plane of the magnetic meridian.

The sine galvanometer, invented by Pouillet, is represented in Fig. 1269. A longer magnetic needle may be employed in this instrument, because it is kept at right angles to the axis of the coil

through which the current passes. A horizontal, graduated circle, containing a declination needle, is fixed within a vertical circle, the two turning on a vertical axis which passes through the centre of a lower stationary, horizontal, graduated circle, an index being used to measure the arc of revolution. A stout copper wire, covered with silk, is passed one or more times around the rim of the vertical circle, according to the strength of the current which is to be measured. For weaker currents the coils are increased. In using the instrument, the plane of the vertical circle is placed in the plane of the magnetic meridian. The needle and index will then each stand at 0, respectively on the upper and lower horizontal circles. If a current is now sent through the wire, the needle will be deflected; and if the vertical circle is rotated till the needle lies in its plane, and therefore again points to 0, the deflection will be marked by the index on the lower circle. The deflecting force of a current acting at right angles to the axis of the needle exactly balances the magnetic force of the earth, which is proportional to the sine of the angle which the needle makes with the magnetic meridian.

1269.

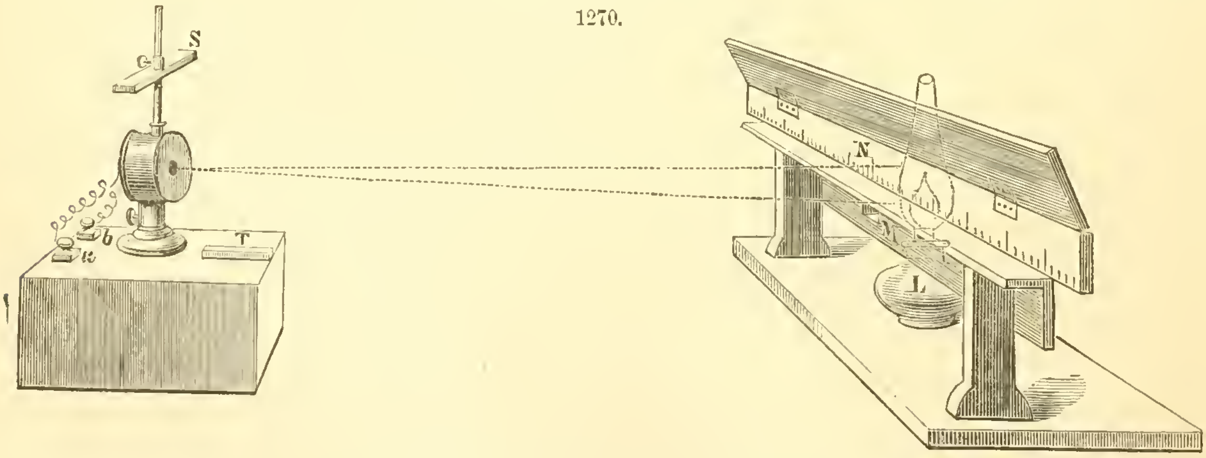


An instrument called a differential galvanometer is sometimes used to measure at the same time the difference in strength of two currents. For this purpose two separate coils of the same sized wire are passed an equal number of times around the same needle. When two currents are sent in contrary directions through the coils, the amount of deflection produced will indicate the difference in strength between them.

Sir William Thomson's mirror galvanometer, Fig. 1270, measures a delicate galvanic current with more precision than any other instrument that has been invented. A magnet is suspended within a coil of wire which varies in size and length according to the size and length of the conductor through which the current has already passed. If it has passed through long circuits containing bad conductors, the coil should be long and of fine wire, because the current will have been so much weakened that a fine long wire is now sufficient to conduct it, and therefore it may be used to induce a considerable magnetic force. The coil is placed within the cylinder mounted upon the rectangular box shown in the figure, and to one side of the magnet suspended within it there is attached a mirror which reflects a ray of light upon a horizontal graduated screen in front of it, and behind which there is placed a lamp which sends a ray of light through an orifice. A slight deflection of the magnet, which together with the mirror weighs only a few grains, gives the reflected ray a wide range over the graduated screen. A bar magnet, *S*, placed in the magnetic meridian, is used to counteract the earth's magnetism and thereby increase the delicacy of the instrument. Another bar magnet, *T*, perpendicular to the magnetic meridian, is used to adjust the instrument to zero when no current is passing.

An instrument called a rheostat, invented by Wheatstone for the purpose of comparing resistances, is represented in Fig. 1271. Two cylinders of equal diameters turning upon their axes are held in a

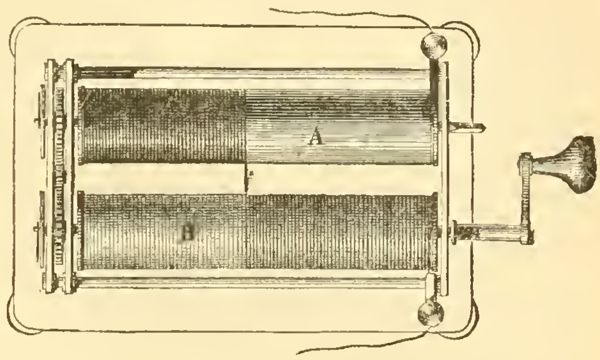
1270.



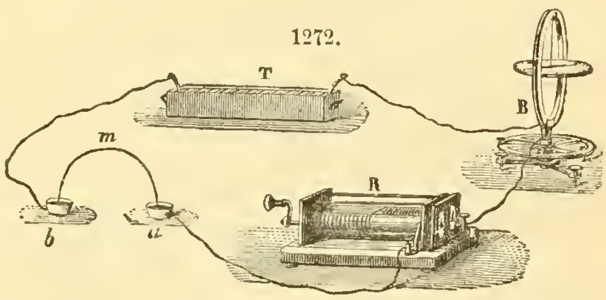

frame. One of them, *A*, is of metal, and the other, *B*, of some non-conductor, as vulcanite or baked wood. There is a spiral groove in the non-conducting cylinder in which a wire, connected with the binding-screw *C*, is wound for an indefinite distance, and then transferred to the other cylinder and wound upon it to its further end. By turning the crank connected with one of the cylinders, the wire may be all transferred from one to the other. A binding-screw connects with the metal cylin-

der; and when this and the other binding-screw are connected with the electrodes of a battery, a galvanic current will pass through the wire which is wound upon the non-conductor, and also through the metal cylinder, so that it will be easy to interpose in the circuit any desired length of wire having any desired area of cross-section. Establishing a certain length of a certain sized wire as a unit of measure, a comparison may be made between the resistances of various media. To measure the resistance of any conductor, the rheostat and sine galvanometer may be used in the following manner: In Fig. 1272, let *m* be a conductor whose resistance is to be measured or compared. One end of it is dipped in a cup of mercury, *b*, which is also connected with one pole of a battery, *T*. The other end of *m* dips into a second cup of mercury, *a*, which is connected with one of the binding-screws of the rheostat. A wire attached to the other binding-screw is connected with one end of the wire which passes around the vertical circle of the galvanometer, the other end of which connects with the other pole of the battery. The rheostat wire is all wound on the metal cylinder, and, the circuit being closed, the deflection of the galvanometer may be noted. Then the conductor *m* is removed from the circuit, and the two wires at *a* and *b* are joined. Enough of the rheostat wire is now wound on the non-conducting cylinder to cause the same deflection in the needle as before. That portion of the rheostat wire through which the current passes will have the same resistance as that of the conductor *m*, whose amount is therefore found by comparison.

1271.




1272.




The results obtained from numerous experiments upon the conductivities of various metals show that silver, gold, and copper are the three best conductors, and that impurities greatly increase resistance, as does also an increase of temperature. It has been shown by Forbes that metals have proportional conductivities for heat and for electricity, and that impurities also proportionately increase the resistance for each. The following table gives E. Becquerel's determinations of specific electrical resistances at 15° C., regarding that of silver at 0° as 100:

| | | | |
|---|---|---|---|
| Silver | 107 | Tin | 734 |
| Copper | 112 | Iron | 825 |
| Gold | 155 | Lead | 1213 |
| Cadmium | 407 | Platinum | 1243 |
| Zinc | 414 | Mercury | 5550 |

ELECTROMOTORS. Motors actuated by the attraction and repulsion of electro-magnets exist in numerous forms. The commonest and simplest is the rotating cylinder, having arms of metal, which serve as armatures, to be attracted or repulsed by electro-magnets disposed radially about the periphery of the cylinder. A commutator connects the current in proper manner to the electro-magnets successively, which are thus excited at such intervals as to attract the cylinder and cause it to rotate continuously. The older forms of this engine were made on the reciprocating plan. No attempts to adapt it for general use as a motor have been successful—on account, first, of the practical difficulties in the construction of the machine itself, and second, of its great lack of economy as compared with the steam-engine. The best results obtained have been from small machines, in which economy of fuel, etc., is no especial object. It has in such form been adapted for operating sewing machines, dental drills, small printing presses, and other light machinery; but its value is not permanent, as it deteriorates rapidly, especially through the destruction of the commutators, and involves the constant care and renewing of the batteries.

On the other hand, the actual efficiency of the electric engine is about four times that of the best steam-engine; but when the relative cost of zinc and coal is considered as materials of consumption, this advantage is much more than counterbalanced. It may be demonstrated that in the Daniell battery, the liquid used being a solution of sulphate of copper, the heat produced by the solution of 1 lb. of zinc is 3,006 thermal units, and that consumed is 1,587 thermal units, leaving the total quantity of heat developed 1,419 thermal units. This multiplied by 772 foot-pounds gives 1,095,468 foot-pounds for the amount of energy developed by dissolving 1 lb. of zinc in a Daniell battery, equal to one-tenth part of the energy developed by burning 1 lb. of carbon. Similarly, it may be shown that in Smee's battery 694,800 foot-pounds of mechanical energy are developed. This last is about one-sixteenth part of the energy developed by burning 1 lb. of carbon. Now it has been stated that the actual efficiency of the electro-magnetic engine is four times that of the steam-engine; hence, the work performed per pound of zinc would be four-tenths of the work per pound of carbon in the first instance above given, and four-sixteenths in the second. Consequently, therefore, the working expense per pound of zinc consumed must fall until it is from four-tenths to one-quarter of the working expense of the most economical steam-engines per pound of carbon, or of coal equivalent to

carbon, before the electromotor can hope to equal the steam-engine in point of economy. According to Van der Weyde, the ratio of the cost of electricity as a motive power as compared with that of steam is as 500 to 1, the price of zinc being estimated at 12½ cents and of coal at ¼ cent per pound. Allowing for the superior efficiency of the electric engine, he determines the expense of running the latter to be about 100 times that of the steam-engine. (See *Manufacturer and Builder*, iii., 150, 172.)

Many misinformed inventors have attempted to build electromotors on a supposed principle that a given battery is capable of magnetizing any number of magnets. This is wholly without foundation. According to Ohm's law, a battery works to its utmost capacity and utmost result when the resistance which the discharging wire offers to the current is equal to the resistance which the battery itself offers to the passage of the same current. Metals are much better conductors than fluids, surpassing them several million times; copper wire conducts the currents 20,000,000 times better than the best solutions in the battery, to which the resistance of the porous cups has to be added; consequently a Bunsen battery of two cups is able to discharge its current through many miles of copper wire, without experiencing a resistance greater than the current has to overcome in the battery itself: how many miles may be easily calculated from the dimensions of the battery, thickness of wire, etc. As long as the length of the wire is below this, the whole power of the battery is discharged, and no change in the currents of the wire and its effects on electro-magnets can be perceived, though the length of this wire be increased and say 4, 8, or even 20 or 50 electro-magnets be charged. As soon as the number of magnets is augmented so that the length of the wire surrounding them exceeds the limit at which the resistance it offers to the current is equal to the resistance offered by the battery, the whole power of the battery can no longer be discharged, and the power of the individual magnets will begin to decrease.

A good review of the various attempts which have been made in Europe to construct an economical electromotor will be found in Figuier's "Merveilles de la Science." Dubs, "Electro-Magnetismus" (Berlin, 1861), deals with the subject quite fully. An interesting controversy regarding an alleged electromotor of great power appears in the *Scientific American*, vol. xxv.

An advantageous application of the electro-magnetic engine has been made in Phelps's electromotor telegraph (see TELEGRAPHIC APPARATUS), where it is used to operate the type-wheel and printing mechanism, hitherto driven by means of a weight and wheel-work. The motor consists of 8 electro-magnets arranged in a circle, within which a revolving shaft carries a circular row of soft-iron armatures, 5 in number. The commutator is so connected that the electro-magnets act successively as the armatures come within their influence, and cease to act just as the latter arrive at a point opposite to the poles of the magnets. By this means a constant attraction is exerted upon the armatures, which causes the shaft to revolve with great rapidity. The motor is provided with a centrifugal governor, which acts to reduce the quantity of electricity flowing through the actuating magnets whenever the speed becomes too great, by which means its motion is rendered perfectly uniform. The magnets are of ordinary form, having cores 0.5 inch in diameter and 1.25 inch in length, wound with insulated copper wire 0.042 inch in diameter. The local battery which drives the motor consists of two large Bunsen cells (see ELECTRO-GALVANIC BATTERIES), charged with Poggendorff's bichromate solution in contact with the carbons in the porous cell, and diluted sulphuric acid in the outer or zinc cell. The containing jars are of glass 9 inches in diameter and 6 inches high. The zinc cylinders are 8 inches outside diameter and 0.5 inch thick. Each contains a porous cell 7.5 inches in diameter. The carbon element consists of two rectangular plates placed parallel and about 2 inches apart, each plate being 5 by 6.5 inches. This battery will run a motor continuously for 15 hours without requiring a renewal of the bichromate solution. A complete description of this apparatus will be found in "Electricity and the Electric Telegraph," Prescott, New York, 1877. A good historical account of electromotors appears in "Les Merveilles de la Science," Figuier, Paris, no date, vol. ii., 385.

TRANSMISSION OF POWER BY ELECTRICITY.—For the transmission of power from a steam or water motor initially, the following system has been adopted: First, a strap or belt from the motor was carried to the pulley of the driving dynamo-electric machine which generated the current. By leading-wires of the required length, the electrical current generated in the first machine was conveyed to the terminals of a second and precisely similar machine. Thus the first machine generated the current, which was utilized in imparting motion to the second machine. The greatest work was yielded by the second machine when the strength of the current given by the first machine or source had been reduced to one-half by the induced current from the second machine. Supposing two equal machines arranged for the transmission of power, the amount of work reclaimable from the second machine would be 50 per cent. of that employed upon the first; and the number of revolutions of the armature of the second machine, corresponding to the maximum of work reclaimed, would be half the number made by the first. Experiments also proved that the loss of efficiency was proportional to the added resistance. (See *Engineer*, xlv., 96.)

At the electroplating works of the Société du Val d'Osne in Paris, two Gramme machines have been used in the above manner, one being connected to the driving-shaft of the works, producing a current which sets machine No. 2 in motion, and this in turn drives the machine which supplies current for the baths. Motive power is thus transmitted over a distance of about 400 feet by means of a single copper wire. The system, says M. Cadiat in *La Nature* (1878), has worked perfectly and uniformly for two months. The velocity can be easily regulated by interposing resistance in the circuit. If, in the circuit from machine No. 2 to the electroplating machine, a copper wire 6.4 feet long and 0.06 inch in diameter be inserted, the velocity falls from 750 to 40 turns per minute; with an iron wire 4.8 feet long and 0.32 inch in diameter, the velocity is reduced to 100 turns. As for the power required, the author states that the starting or stopping of the system is not recognizable by the engineer who controls the driving-engine of about 10 horse-power, from which power is also taken for a variety of tools.

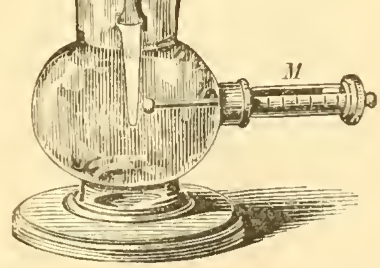
The statement has been made by Dr. Siemens that a continuous rod of copper 30 miles long and 3 inches in diameter is capable of conveying that distance electrically energy equal to 1,000 horse-power. This has been discussed by Mr. N. S. Keith in a paper read before the American Institute of Mining Engineers, May 7, 1877 (republished in the *Engineering and Mining Journal*, July 7, 1877). In planning a theoretical machine to suit the conditions of the problem, he points out that it will require 746,000 vebers current or their equivalent in energy to utilize 1,000 horse-power as electricity for dynamic purposes.* He says: "We may therefore use electromotive force of 1,000 volts, resistance of 1.34 ohm, and a current of 746 vebers; thus, $\frac{1000\ E}{1.34\ R} = 746\ C$. In other words, the dynamic equivalent of 746,000 vebers may be had by multiplying the electromotive force 1,000 by the current 746. It has been found that a discharge of the magnetism of a soft-iron core induces a current in the coil surrounding it possessing electromotive force of one volt for about each 25 feet of coil. The quantity or current comes from the strength of the magnetism and number of discharges. For 1,000 volts electromotive force 25,000 feet in length of copper wire or strips, weighing 1.2 lb. per foot length, or in all 30,000 lbs., may be taken. This will have a resistance of .66 ohm. It should be wound upon a core of iron weighing 10,000 lbs. This core and coil, constituting what is called an armature, must be revolved between the poles of an electro-magnet having such an attraction for the armature as to call for the expenditure of 1,000 horse-power in revolving it. Such a magnet will weigh probably 60,000 lbs., and have a like weight of copper in its coils. It should be excited or magnetized by a smaller armature revolved between the poles of a smaller magnet, with an expenditure of say 100 horse-power. This is necessary, because, if the coil of the magnet is part of the main circuit, the resistance will be much increased. The electromotor receiving the current of electricity must have at least the same length of copper in its coils; and as the resistance of the coils (when the machine in motion is exerting its greatest power) is double that which they have at rest, and as it is necessary from our other fixed resistances to make the resistance of the machine .50 ohm, we make the weight of copper coils per foot 3.17 lbs., a total of 79,200 lbs., with a weight of iron about 70,000 lbs." The cost of this apparatus is estimated at $33,200.

"The energy of 1,000 horse-power expended on the machine generating the electric current is distributed throughout the circuit in proportion to the special resistances of the several parts. The armature, having a resistance of .66 ohm, absorbs 66-134, or 492.5 horse-power; the conductor 18-134, or 134.3 horse-power; the motor 50-134, or 373.2 horse-power. This last amount is all that can be utilized with this arrangement, even if there is no loss. The electric machine and the motor may be made larger, or two may be used, making the resistances of them one-half as much, but not with any increase of utilizable power, as the resistance of the conductor remains the same. Estimating a resistance of .33 ohm for machine, .18 ohm for conductor, and .25 ohm for motor, and we have 33-76 or 434 horse-power for machine, 18-76 or 237 horse-power for conductor, and 25-76 or 329 horse-power for motor. This is less available power than before. The resistance of the earth returning the current we may count as nothing. Under no circumstances can we utilize the full power expended. If we decrease the resistance of the machine to .33 ohm, and increase that of the motor to .83, keeping total resistance the same, we will gain. Then the machine will absorb 33-134 or 246.2 horse-power, the conductor 18-134 or 134.3 horse-power, and the motor 619.5 horse-power. With a larger conductor or shorter distance, this proportion may be increased. There are various sources of loss, especially with electricity of such electromotive force and tension. There is no doubt that at least 50 per cent. of the energy expended on a magneto-electric or dynamo-electric machine at a waterfall may be used at a distance by an electro-magnetic motor as mechanical power. The amount of heat developed throughout the entire circuit will be equivalent to that from the combustion of 200 lbs. of coal per hour, or 42.746 heat units per minute. That proportion due to the armature, having resistance of .33 ohm, is sufficient to raise its temperature 1° C. per minute. Of course, then, some arrangement for cooling by water must be applied."

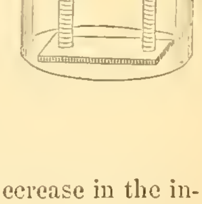
ELECTROPLATING. See ELECTRO-METALLURGY.

ELECTROSCOPES are instruments for the purpose of detecting the presence of free electricity, and also its nature. Hare's electroscope, Fig. 1273, consists of a glass vase, through the side of which is inserted a wire having a brass knob on its end, which may be approximated by means of a screw cut upon its circumference to within a very minute distance of a single strip of gold leaf. The intensity of the electricity through a space of air being found to decrease in the inverse ratio of the squares of the increased distances, this instrument becomes thus exceedingly sensi-

1273.




1274.




* "A veber of current represents the energy set free by the combustion of 11 grains of carbon, or 11 grains, about, of coal, or 1 grain of hydrogen, with a development of 6 units of heat in 6,338 seconds. That amount of free or sensible heat is set free in the circuit. Thus, one volt of electromotive force forces one veber of electric current through a circuit of one ohm resistance, requiring to do so 4,673 foot-pounds of energy, with a development of 6 units of heat in the circuit in 6,338 seconds. The heat set free is the exact measure of the force used."

tive to the slightest disturbances of electrical matter in the gold leaves propagated from the metallic cap, which is made of zinc. By means of this simple instrument, one of the most important facts in the whole science of electricity may be experimentally demonstrated, by bringing into contact with the plate various kinds of metals, as a copper plate insulated by a glass handle. A disturbance of the natural electrostatic condition of the zinc plate and of the gold leaves suspended therefrom is producible by the simple approximation and contact of various bodies with the plate; the sifting of various pulverized substances thereon being sufficient to produce the movement of the gold leaf. Both of these metallic plates may be separately examined by the test of the contact with other electroscopes composed of pith balls or flexible gold leaves, and no signs of electricity will be discoverable. Now place the plate of copper on the plate of zinc, which is called the "cap of the electroscope," and hold one hand in contact with *M*, which is to be screwed up until the ball at the end of it is brought close to the tip end of the pendent strip of gold leaf; and with the other hand touch the copper plate, and then lift it by the glass handle from the zinc. At the instant the separation is effected, the gold leaf will be seen to strike the ball if the latter be previously brought to within the distance of one-twentieth of an inch from the former. This instrument serves the purpose of a delicate *electrometer*, to measure very minute degrees of intensities of electrical action. Bohnenberger's electroscope is represented in Fig. 1274. In this two voltaic piles stand with their opposite poles upon a metal plate, and from the top of a bell-glass which covers the piles a strip of gold leaf is suspended from a conductor which passes through the top and terminates in a knob. The gold leaf hangs between the two knobs of the piles, and the instrument is so delicate that whenever a body only slightly electrified is brought within a few feet of it, the gold leaf will move toward one or the other of the piles. A pith ball suspended by a silk thread between them will oscillate as long as the chemical action of the pile continues, which may be for two or three years.

Another form of gold-leaf electroscope consists of a circular brass plate having rounded edges, which carries a stout brass wire cemented by shellac into a glass tube which passes through a wooden cap fitted by a groove upon the top of a bell-jar. The lower end of the wire supports a horizontal brass cross-piece about an inch in length, flattened in a vertical plane and made very thin. Each side of the cross-piece is smeared with a little strong gum and laid upon the edge of a rectangular strip of gold leaf about 1 inch by 5 inches in dimensions. The leaves hang thus face touching face. On the inside of the bell-jar, opposite to one another and each facing one of the gold leaves, are sometimes pasted two strips of tin foil, of such height that they are touched by the leaves on the extreme divergence of the latter. These strips reach to the stand if it be of metal; or if it be of wood, they are horizontally prolonged and carried over the edge to the earth. A shallow cup contains quicklime, chloride of calcium, or strong sulphuric acid, to keep dry the inside of the jar.

ELECTROTYPING. See Electro-metallurgy.

ELEVATED RAILWAY. See Railroad.

ELEVATORS AND LIFTS. Suspended platforms or boxes known as elevators are largely used now to raise passengers and freight from the lower to the upper stories of high edifices. Since their introduction buildings are carried much higher than before. The structure of the Western Union Telegraph Company in New York has ten stories above the street which are occupied as offices, while the New York *Tribune* building has twelve such stories. Without a passenger elevator the upper stories would be practically inaccessible.

*Power required for Elevators.*—The useful power required for operating an elevator is very small. That employed to run either of the sets of elevators in two of the largest buildings (the Western Union Telegraph and *Evening Post* buildings) in New York City amounts to less than $\frac{1}{20}$ of a horse-power.

*Classes of Elevators.*—Elevators in general use may be divided into two general classes: 1. Steam elevators, where the rope lifting the car is wound round a drum turned by a steam-engine; 2. Hydraulic elevators, where the rope lifting the car is connected with a motor worked by water. In addition to the motor, the hydraulic elevator must have a pump to lift the water from the cellar to the tank above.

The reasons why steam elevators are so wasteful of power are: 1. The low steam-pressure and the great back pressure in the steam cylinders; 2. The small size of the cylinders; 3. The large proportion of power expended in overcoming friction on engine and car; 4. The fact that the engine runs while the car is descending, thus requiring a cylinder full of steam at least atmospheric pressure. The following are the pressures on the indicator card of the engine running the elevator in the Western Union building while carrying passengers:

| | Up. | Down. |
|---|---|---|
| Initial pressure above zero | 32.0 | 24.5 |
| Terminal pressure above zero | 26.6 | 22.1 |
| Mean back pressure above zero | 22.6 | 20.4 |
| Indicated pressure | 6.7 | 2.9 |
| Friction of engine and load | 9 0 | |

The causes of the waste of power in hydraulic elevators are: 1. The ordinary steam-pump not being an economical machine; 2. Having to use a cylinder full of water whether the car is fully loaded or not; 3. The large proportion of power absorbed by the friction of the machine.

In the machine in the *Evening Post* building, the dimensions are as follows: Height from surface of water in well to surface of water in tank, 140 feet; diameter and stroke of hydraulic cylinder, 36 × 96 inches; lift of car, 96 feet. From these data may be calculated the following: Total unbalanced load in car, equivalent to 140 feet of water on plunger, 6,000 lbs.; number of round trips

in 6 hours, 170; actual load carried each round, calling each passenger 140 lbs., 960 lbs. Thus it appears that five-sixths of the head of water is wasted.

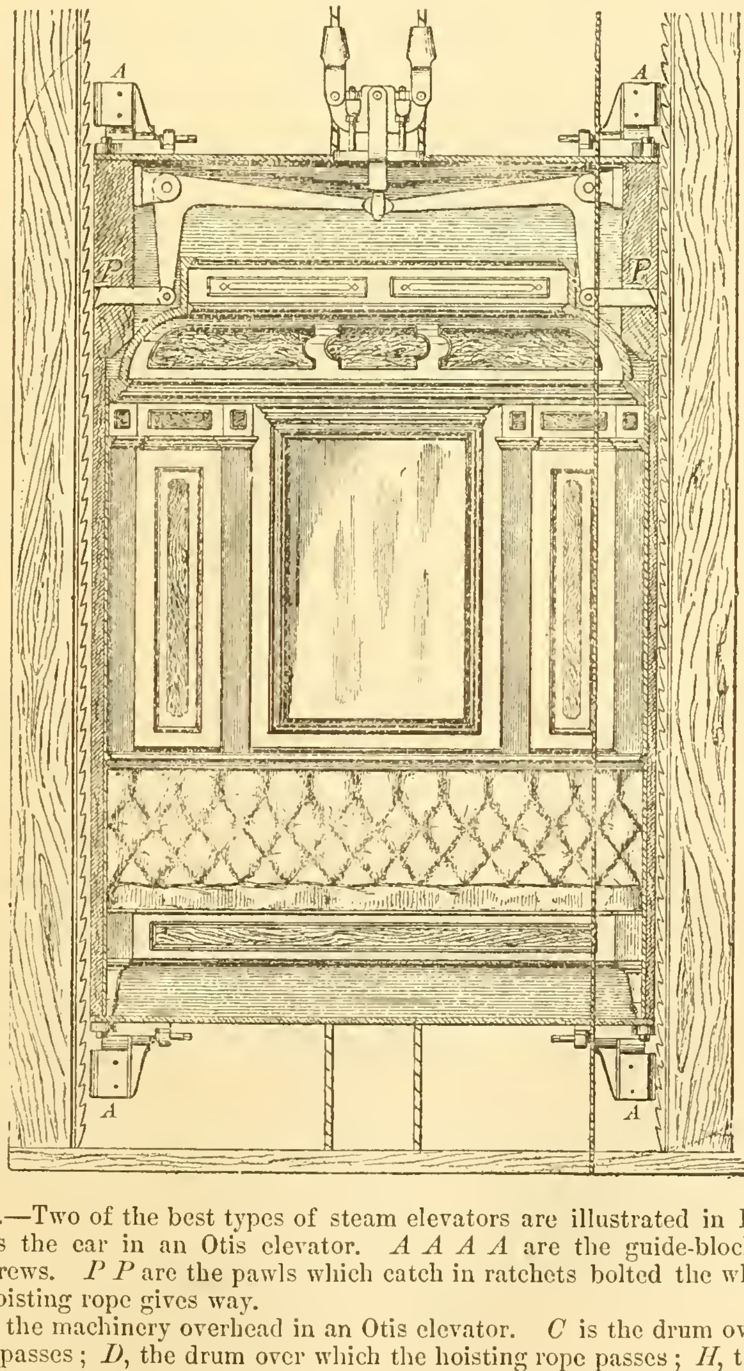
The cars of both the hydraulic and steam elevators are generally in part counterbalanced. The counterbalance is always much lighter than the car, in order to be certain that the car will not stick fast on its passage and then drop suddenly after the rope has become slack. There are various devices called "safeties" to prevent this, which will be described in the proper place.

The cost of running by steam a large elevator, like that in the Western Union building, for a year of 300 days, 8 hours a day, may be reckoned as follows:

| | |
|---|---|
| Interest on cost of elevator, engine, and boiler, $10,000, at 7 per cent..... | $700 |
| Annual repairs, 5 per cent | 500 |
| Sinking fund, 3 per cent | 300 |
| Engineer, at $60 per month | 720 |
| Attendant, at $40 per month | 480 |
| Coal, 600 lbs. per day, at $6 per ton | 540 |
| Total | $3,240 |

In cities where the municipal authorities will furnish water, hydraulic elevators can be run much more cheaply than steam. In other places they are gradually gaining favor from their great simplicity, less first cost, less liability to accident and necessity for repair, and smaller amount of fuel required.

1275.




*Steam Elevators.*—Two of the best types of steam elevators are illustrated in Figs. 1275 to 1219. Fig. 1275 shows the car in an Otis elevator. *A A A A* are the guide-blocks, which may be tightened up by screws. *P P* are the pawls which catch in ratchets bolted the whole length of the guides when the hoisting rope gives way.

Fig. 1276 shows the machinery overhead in an Otis elevator. *C* is the drum over which the rope to counterbalance passes; *D*, the drum over which the hoisting rope passes; *H*, the hand-rope; *W*, the weight which presses the brake on the drum when the hand-rope is thrown up.

1276.

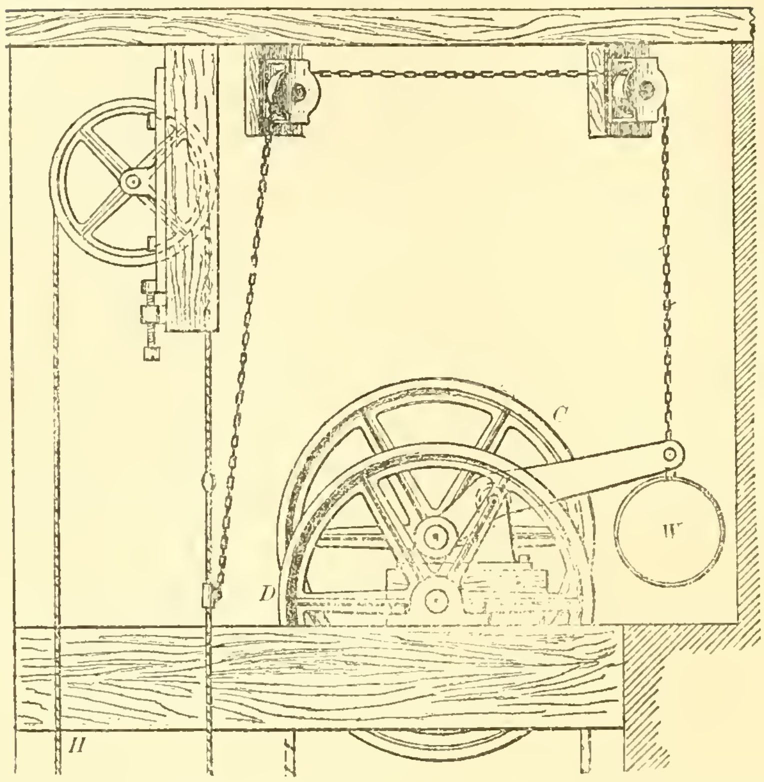
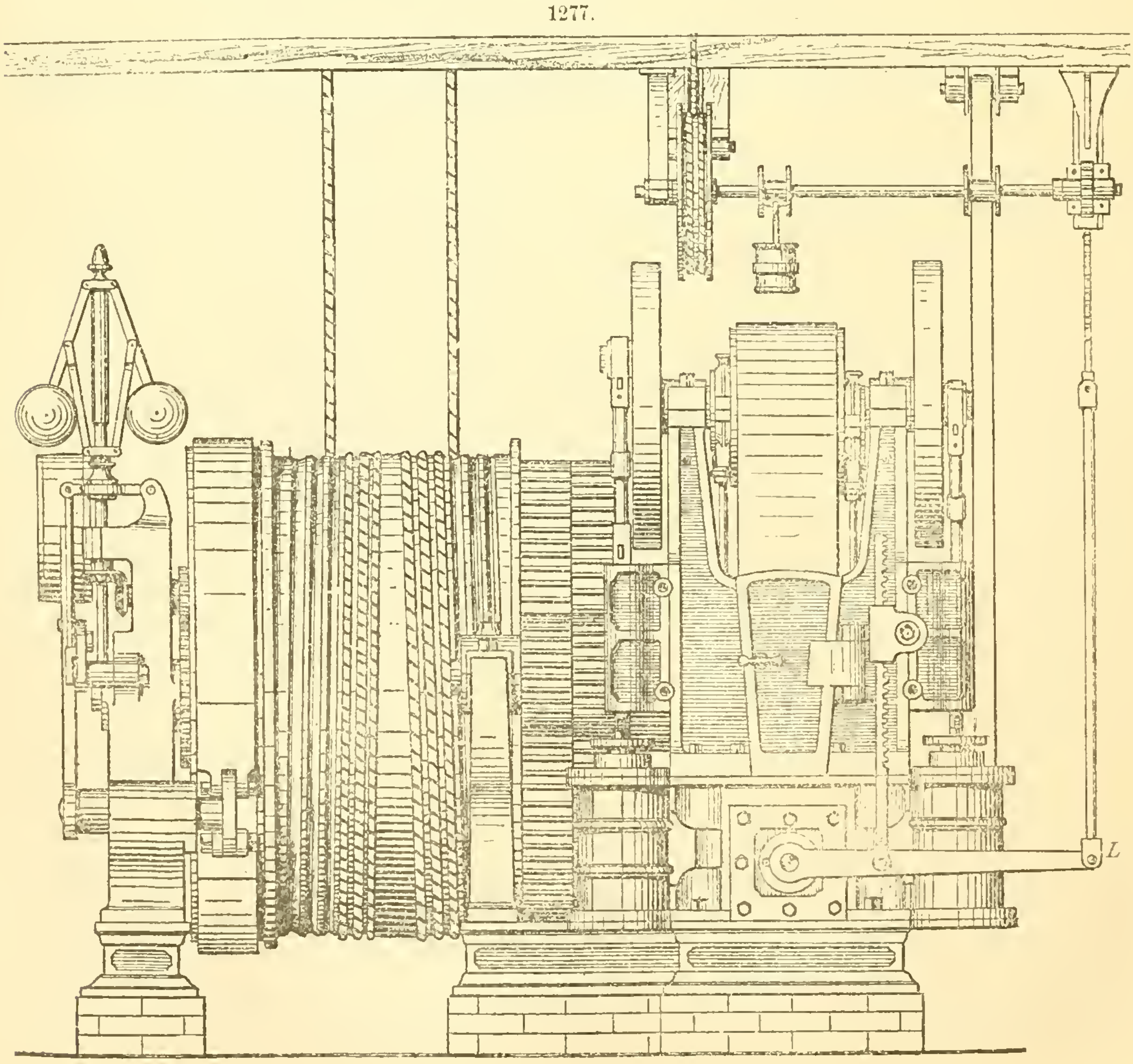



Fig. 1277 is an end and Fig. 1278 is a side view of the hoisting engine for the Otis elevator. *L* is the starting lever connected with the hand-rope. This machine works entirely through gear-wheels, which are apt to be more durable than worms and worm-wheels.

1277.



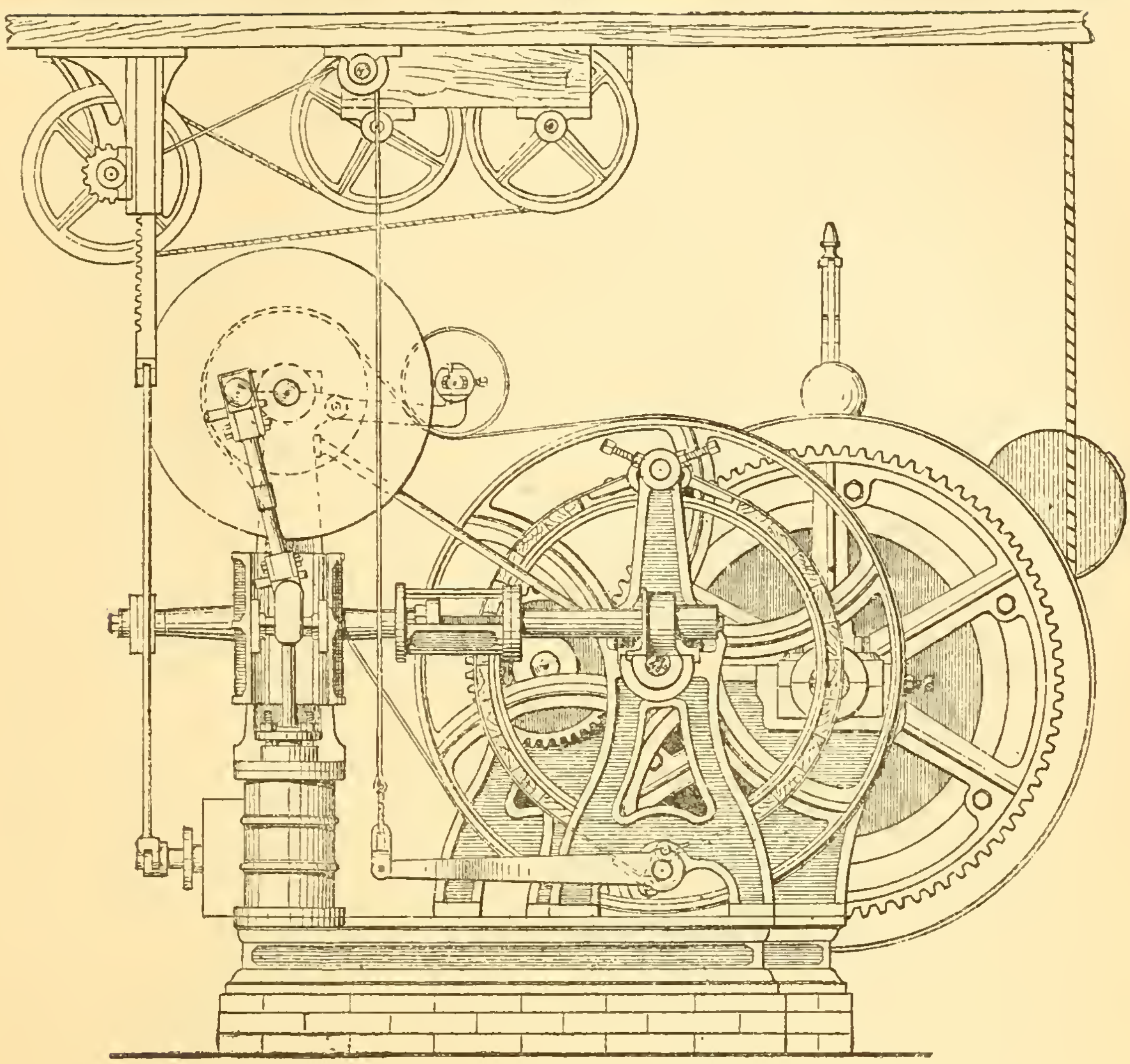
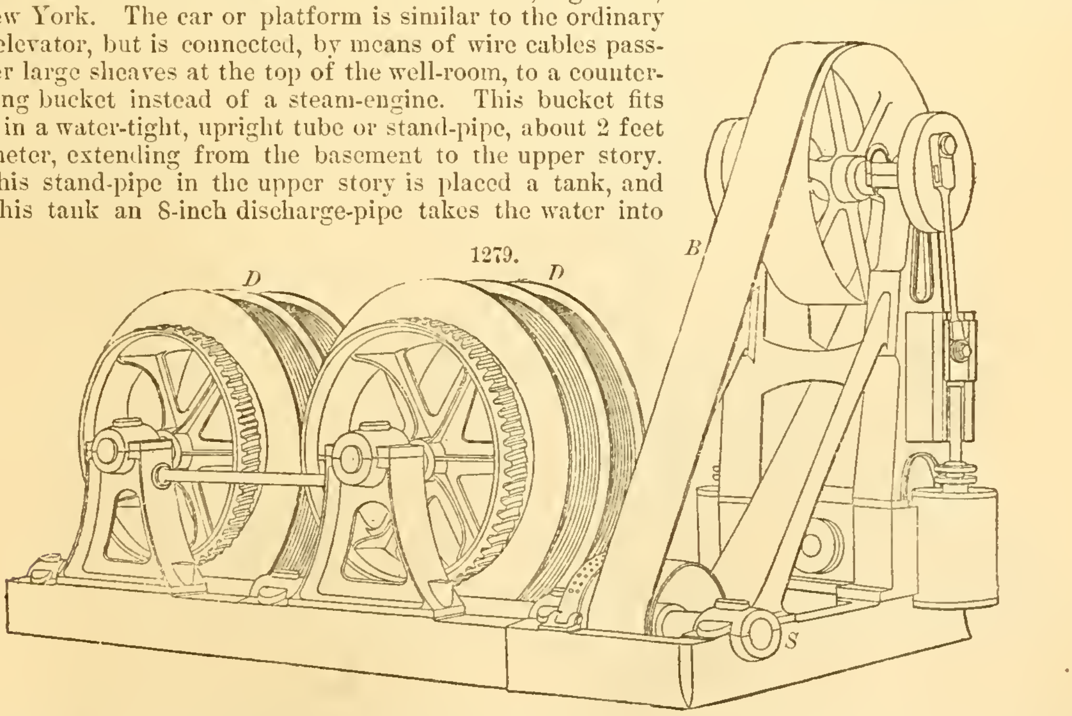


Fig. 1279 shows the Hanford elevator engine. *D D* are the drums, which turn in opposite directions, being driven by right and left worms on the shaft *S*. *B* is the belt driving the worm-shaft. The hoisting ropes and hand-ropes are not shown.

*Hydraulic Elevators.*—The water-balance elevator, Fig. 1280, is in use in the Western Union building, New York. The car or platform is similar to the ordinary steam elevator, but is connected, by means of wire cables passing over large sheaves at the top of the well-room, to a counterbalancing bucket instead of a steam-engine. This bucket fits closely in a water-tight, upright tube or stand-pipe, about 2 feet in diameter, extending from the basement to the upper story. Near this stand-pipe in the upper story is placed a tank, and from this tank an 8-inch discharge-pipe takes the water into

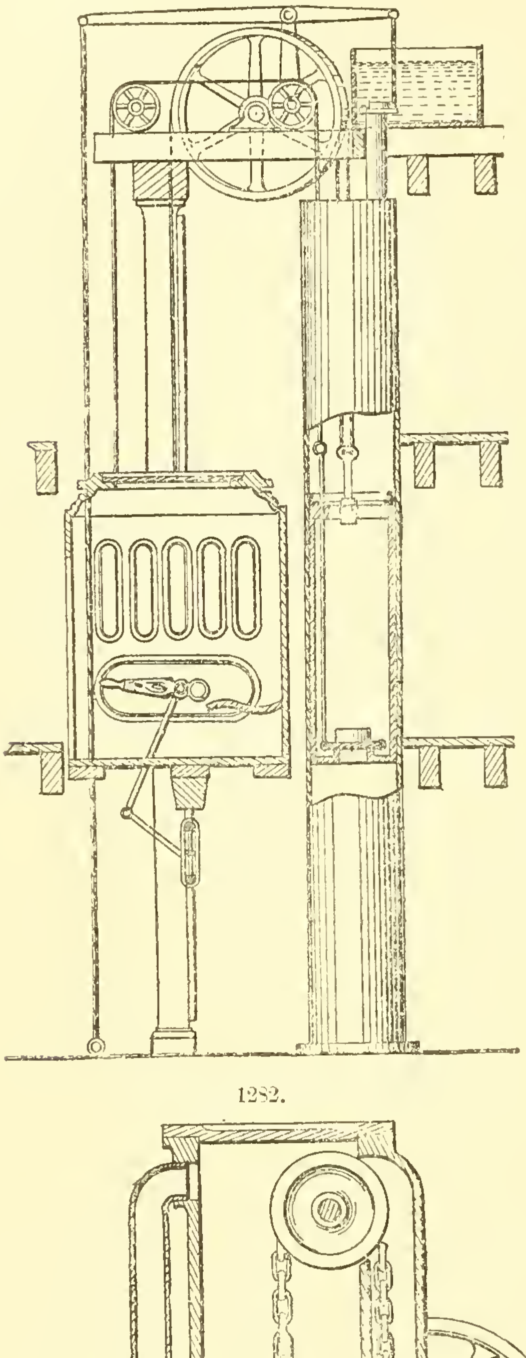
1279.



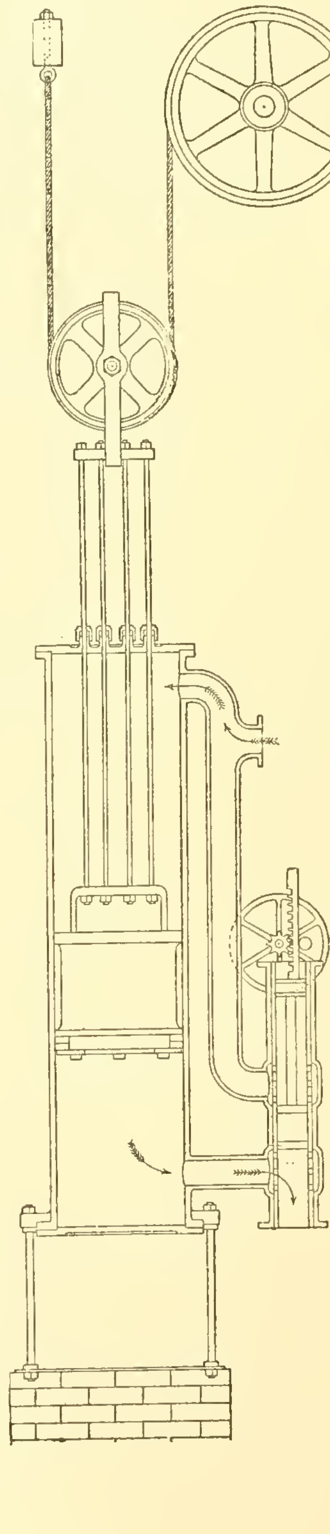

the bucket, which moves up and down in the stand-pipe. A valve in this tank is opened by stepping upon a treadle in the car, and the operator thus takes into the bucket enough weight of water to overbalance the load he then has in the car. As soon as the bucket is heavier than the car,

it descends, and of course draws the car upward, thus using the minimum power required to raise each load, rather than the full power of an engine each and every time. The speed is controlled by means of brakes or clamps, that firmly clasp wrought-iron slides secured to posts on each side of the

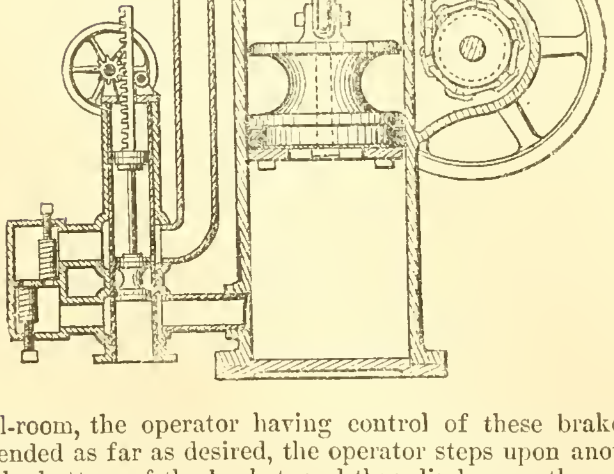
1280.



1281.



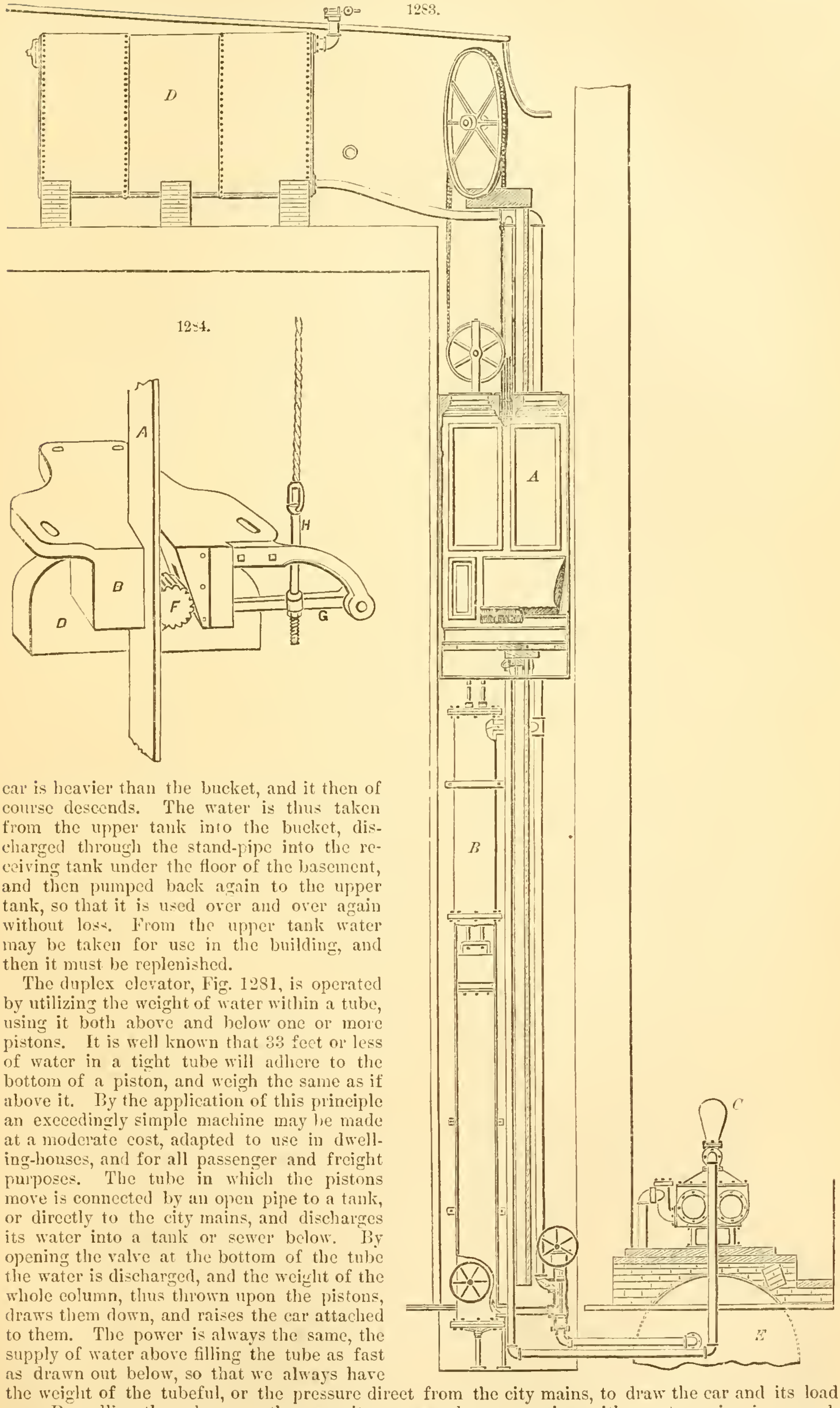
1282.



well-room, the operator having control of these brakes by a lever in the car. When the car has ascended as far as desired, the operator steps upon another treadle in the car connected with a valve in the bottom of the bucket, and thus discharges the water into the receiving tank below until the

1283.

1284.

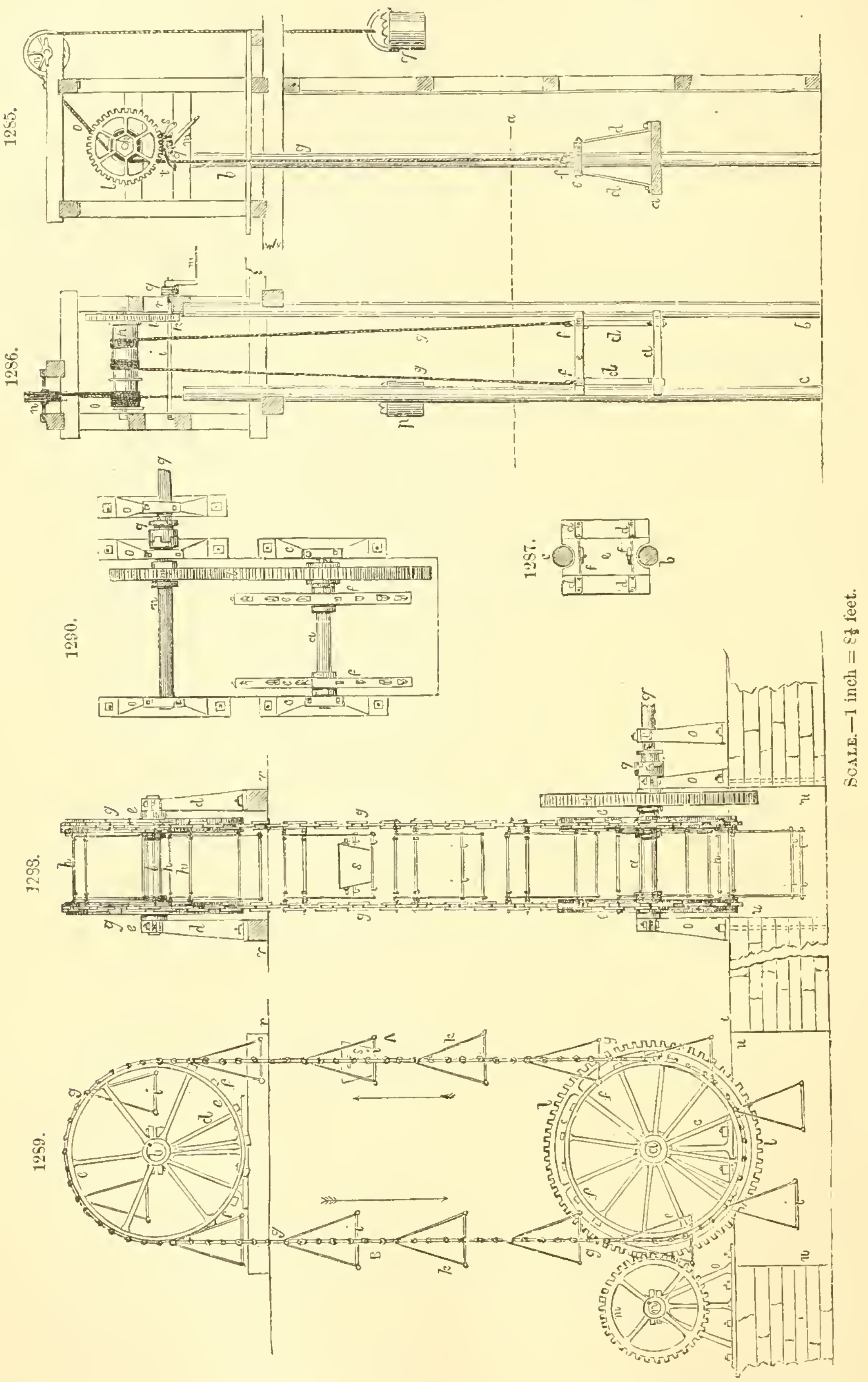



car is heavier than the bucket, and it then of course descends. The water is thus taken from the upper tank into the bucket, discharged through the stand-pipe into the receiving tank under the floor of the basement, and then pumped back again to the upper tank, so that it is used over and over again without loss. From the upper tank water may be taken for use in the building, and then it must be replenished.

The duplex elevator, Fig. 1281, is operated by utilizing the weight of water within a tube, using it both above and below one or more pistons. It is well known that 33 feet or less of water in a tight tube will adhere to the bottom of a piston, and weigh the same as if above it. By the application of this principle an exceedingly simple machine may be made at a moderate cost, adapted to use in dwelling-houses, and for all passenger and freight purposes. The tube in which the pistons move is connected by an open pipe to a tank, or directly to the city mains, and discharges its water into a tank or sewer below. By opening the valve at the bottom of the tube the water is discharged, and the weight of the whole column, thus thrown upon the pistons, draws them down, and raises the car attached to them. The power is always the same, the supply of water above filling the tube as fast as drawn out below, so that we always have the weight of the tubeful, or the pressure direct from the city mains, to draw the car and its load up. By pulling the valve-rope the opposite way, a valve connecting with a return-pipe is opened,

and the car is allowed to descend. The upward and downward motion is perfectly smooth, noiseless, and steady, and free from all jarring or shaking.

Fig. 1282 represents a device for giving a long travel to the car with a short travel to the

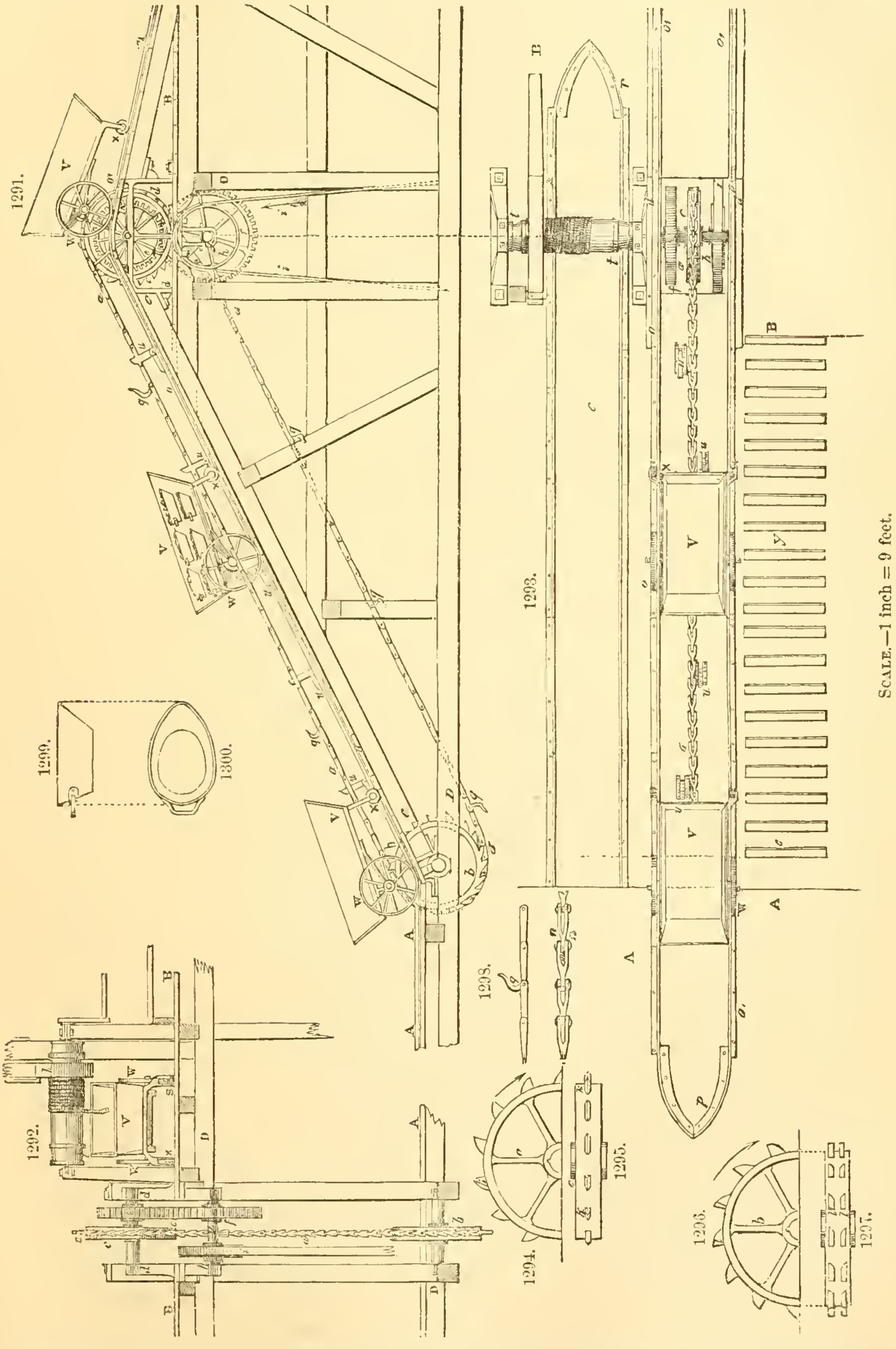



hydraulic piston. The piston is moved up and down by admitting water above and below, and the motion transferred through the chain to the large drum around which the hoisting rope is wound.

Fig. 1283 represents the general arrangement of a hydraulic elevator, in which all the machinery except the steam-boiler is shown. *A* is the car; *B*, the hydraulic cylinder; *C*, the pump; *D*, the reservoir for water on the top of the building; *E*, the reservoir for water in the cellar.

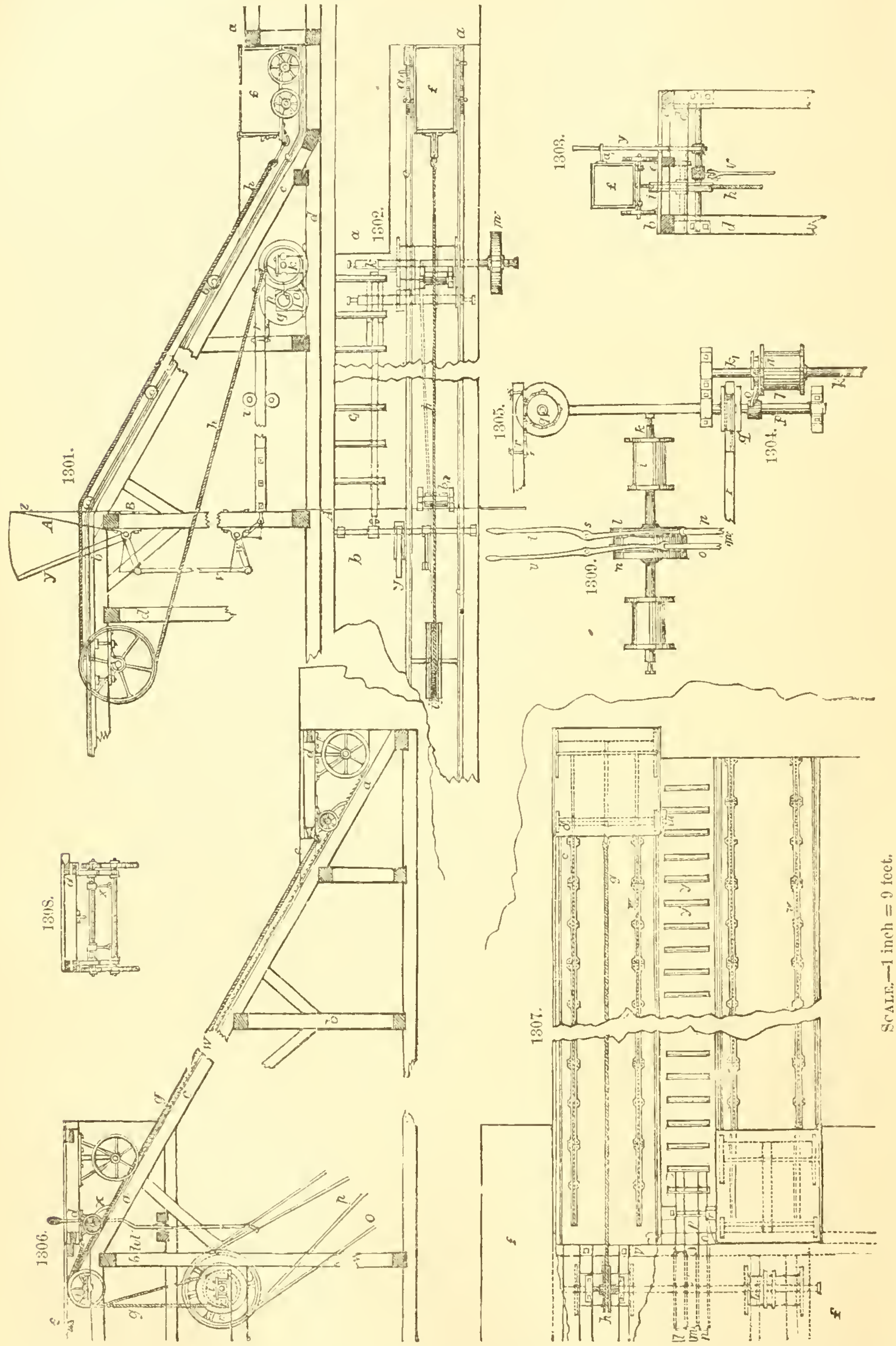
*Safeties.*—These are devices to keep elevator cars from falling in case of breakage of the rope,

Fig. 1284 represents "Baldwin's safety." *A* is a wrought-iron slide, 4 inches by $\frac{1}{2}$ inch. Such slides are firmly bolted to the posts on each side of the well-room, and act as guides to the car, and for holding the same from falling if the ropes should break. *B* is the safety-block. This is made of cast-iron, and is 15 by 16 by 5 inches. Two blocks are used on each elevator, securely attached to the bottom of the platform. *D* is a wrought-iron band, $2\frac{1}{2}$ inches square, shrunken around the safety-block to give it additional strength. *F* is the safety-roll, made of corrugated




steel, $1\frac{1}{4}$ inch diameter. *G* is the finger on which the safety-roll rests, and *H* a rod attached to it. This safety is not operated by springs, but by the weight of the car itself. The breaking or overstrain of one or all of the six cables brings it into action. Four of these cables are attached to the

bottom of the car, through the safety-block. The other two act as safety cables, and do not come into use until the others are overstrained. Whenever this occurs, the weight is thrown on the safety-ropes; by which means the fingers to which they are attached, and on which the safety-rolls




SCALE.—1 inch = 9 feet.

rest, are raised, so as to bring the safety-rolls in contact with the slides (which are stationary and firmly secured to the posts) on one side, and the inclined planes on the safety-blocks on the other—thereby wedging these rolls firmly into the slot, so that it is impossible for the car to go down a single inch until a readjustment is made.

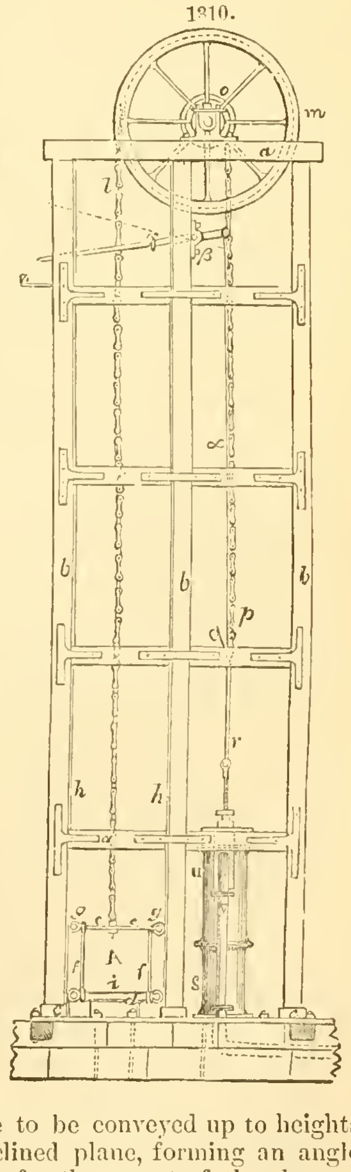
*Miscellaneous Hoisting Apparatus.*—The following illustrations represent small machinery for raising materials in mills, factories, mines, etc. For ice elevators, see ICE-HARVESTING APPARATUS.

*A vertical Elevator, moved by hand.*—Fig. 1285 is a side elevation; Fig. 1286, a front elevation; Fig. 1287, a section on the line *a b*. The weight to be raised is placed on the platform *a* of the frame *a d e*, which, moving between the posts *c b*, is retained in position by grooves in *a* and *c*, as shown clearly in the section, Fig. 1287. The platform is raised by the winding of the chains or ropes attached to the frame at *f* on the barrel *h*, which, if the weight is trifling, is turned by a winch on its own shaft, but more commonly an extra shaft *i*, gear *l*, and pinion *k* are employed with the winch *m*; two ratchet-wheels *q r* and catches *s* and *t* hold the platform in any desired position. A counterpoise *p* is attached by the rope *o*, passing over the pulley *n*, to the barrel *h*.

*A vertical Elevator, driven by steam or water power, used in the iron-works of Belgium.*—Fig. 1288 is a front elevation; Fig. 1289, a side elevation; Fig. 1290, a plan of the lower part. The parts are as follows: The standards *c* and *d* support a lower shaft *a* and upper *b*, to each end of which are fixed the iron wheels *c c*, of about $7\frac{1}{2}$ feet diameter and 7 inches wide, cast with projections *f f*, adapted to the links of the endless chains *g g*; at distances of about 5 feet the two chains are connected by iron rods *h h h*, from which depend the platforms *i k*, on which are placed the loads to be raised or lowered. These weights can be put on or taken off while the machine is in motion; and if from neglect the load is not removed, the only result is that it continues to ascend and descend with the revolutions of the wheels *c c*. Motion is communicated through the shaft *p*, the pinion *m*, and the gear *z*, fixed to the shaft *a*. *q* is a slide coupling; *o o*, standards of the shafts *p* and *n*; and *u*, a pit or span necessary below *a* for the passage of the platforms.

*An Elevator working on an incline, with an endless chain, used at some of the blast-furnaces of Belgium.*—Fig. 1291 is the side elevation; Fig. 1292, the rear elevation; Fig. 1293, the plan. *A A* is the bottom, and *B B* the top platform; *C C* the railway, inclined at an angle of about 30°, and supported by the frame *D D*. The wagons are drawn up by the endless chain *a a a*, resting loosely in the wheels *b b c c*, to which last motion is communicated through the gears *e* and *f* and the pulley *h*, over which passes a band *i* from the prime mover. Figs. 1294 and 1295 represent two views of a portion of the wheel *c c*; Figs. 1296 and 1297, of the wheel *b b*; Fig. 1298, a view of the chain. It will be seen that there is but one row of projections *k k* on the rim of the wheel *c*, fitting the openings *m* of the links of the chain, while on *b* the row is double, and is adapted to the spaces *n n* of the chain.

1310.

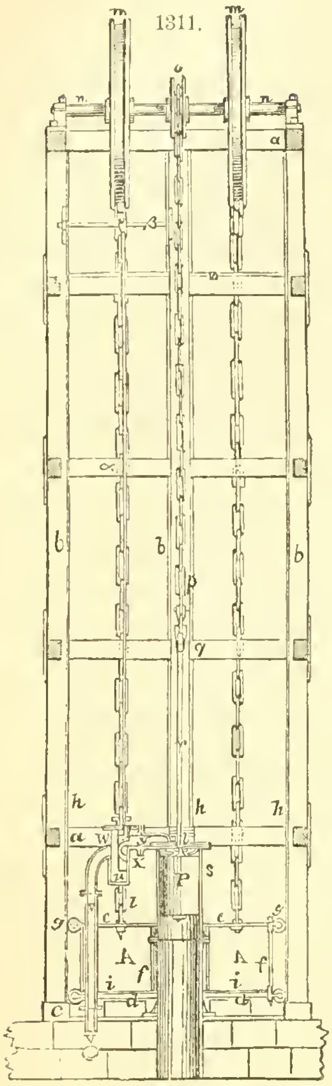


The loaded wagon being brought to the bottom of the incline, the hind axle is caught by one of the hooks *g* (which are about 9 feet apart), and is drawn up. At the top the wagon is received on a small descending railway, inclined at an angle of about 5°, and whose summit is sufficiently above the platform *B B* for gravity alone to carry the wagon to its place of unloading. The emptied wagons are placed on a side track *s s*, and are lowered by means of a rope attached to the windlass *t t*, Figs. 1292 and 1293. Along the railway *o o*, and at a distance of from 5 to 6 feet, are placed the movable catches or bell-levers *u u*, which, in case of the breakage of the chain, will catch the hind axle and stop the descent of the wagon. The wagons used in Belgium are composed of cast and wrought iron, and the materials for supplying the furnace are first put in plate-iron vessels (holding from 30 to 40 lbs., and of the form represented in Figs. 1299 and 1300), and then placed in the wagons, which contain from 12 to 18 of them.

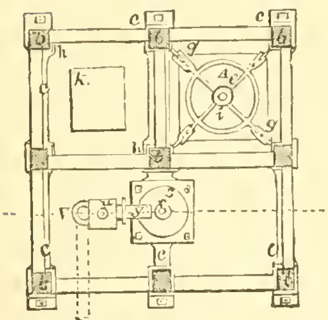
*An Elevator working on an incline with a pulley-rope.*—In blast-furnaces where only charcoal is used, the elevator represented in Figs. 1301 to 1305 is frequently employed. Fig. 1301 is a side view; Fig. 1302, a plan; Fig. 1303, a section on the line *A B*; and Figs. 1304 and 1305 are details. The principal axis $k\,k_1$, Fig. 1304, is at *k*, where the drum *l* is cylindrical, and at $k_1$ squared. On this part is placed the movable wheel *m*, with the knobs *n n*, which are inserted into corresponding holes of the drum *l*, whenever this latter is to follow the movement of the axis $k\,k_1$. In the periphery of the wheel is carved a groove, into which fits the quadrant *o*, Figs. 1301 and 1304, wound like the worm of a screw, and fixed to the shaft *p*. To this shaft is also fixed the disk *q*, Figs. 1301, 1304, and 1305, on whose periphery is placed the bar *r r*, which is joined to it by the counter-chains *s* and *t*, Fig. 1305, in such manner that the wheel, together with the shaft *p* and quadrant *o*, is alternately turned to the left and to the right, according as the bar is pushed backward and forward. By this the wheel *m* is either moved on or off the drum *l*, and consequently the latter is brought in or out of connection with the axis $k\,k_1$.

*A double Elevator working on an incline with pulley-ropes.*—At blast-furnaces where the smelting of the ore is effected by means of coke, and large quantities of iron, stone, fuel, and other supplies are to be conveyed up to heights of 30 or 50 feet, several of these elevators are applied. On the inclined plane, forming an angle of 30° or 40°, are two railways, parallel to each other, the one serving for the ascent of the charged wagon, and the other for the descent of the empty one. An elevator of this kind is represented

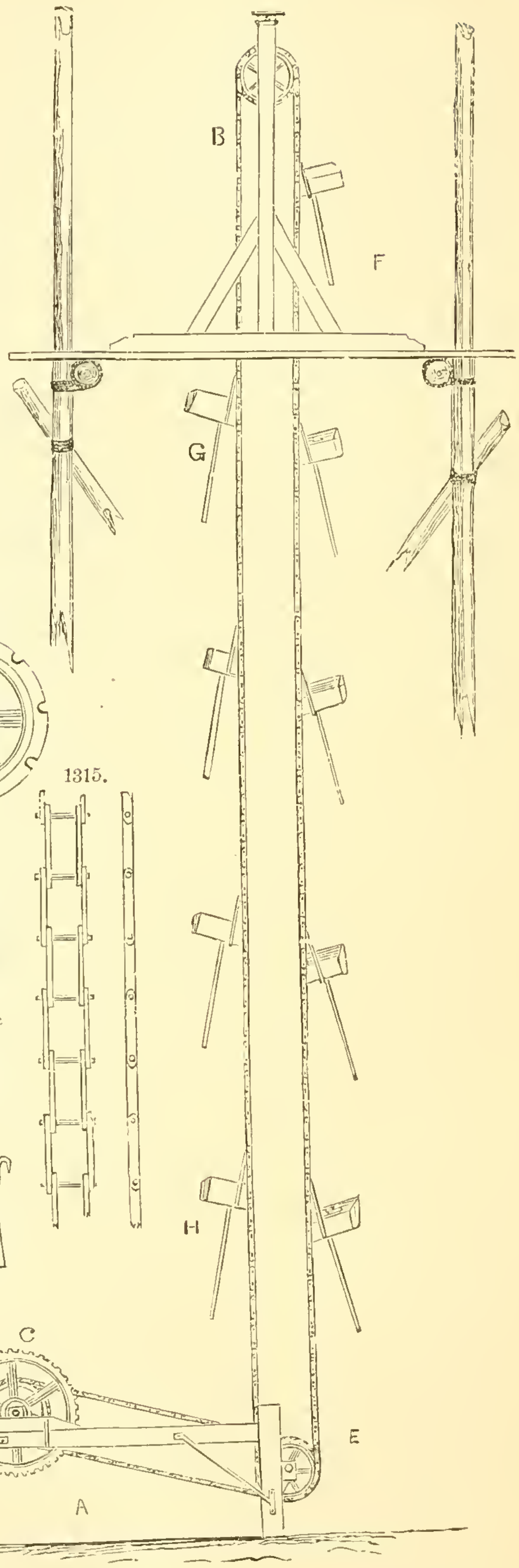
1311.



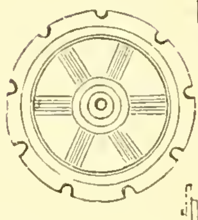
1312.



1313.




1314.



1315.

1316.


in Figs. 1306 to 1309. Fig. 1306 is a side elevation; Fig. 1307, a plan; Fig. 1308, a front elevation; and Fig. 1309 represents the principal axis with its two drums and levers for moving out and in the clutches.

*An Elevator moved by compressed air or pneumatic engine.*—At the iron-works of Chatlinot, near Charleroi, in Belgium, an elevator of this description, and about 50 feet in height, was constructed in 1839, for three blast-furnaces, where the smelting of the ore is effected by means of coke. The compressed air required as motive power was derived from the great wind-reservoir of the blast apparatus, the air here being compressed at the rate of 4 lbs. pressure on the square inch. Fig. 1310 is a side elevation; Fig. 1311, a front elevation; and Fig. 1312, a horizontal section of a part immediately above

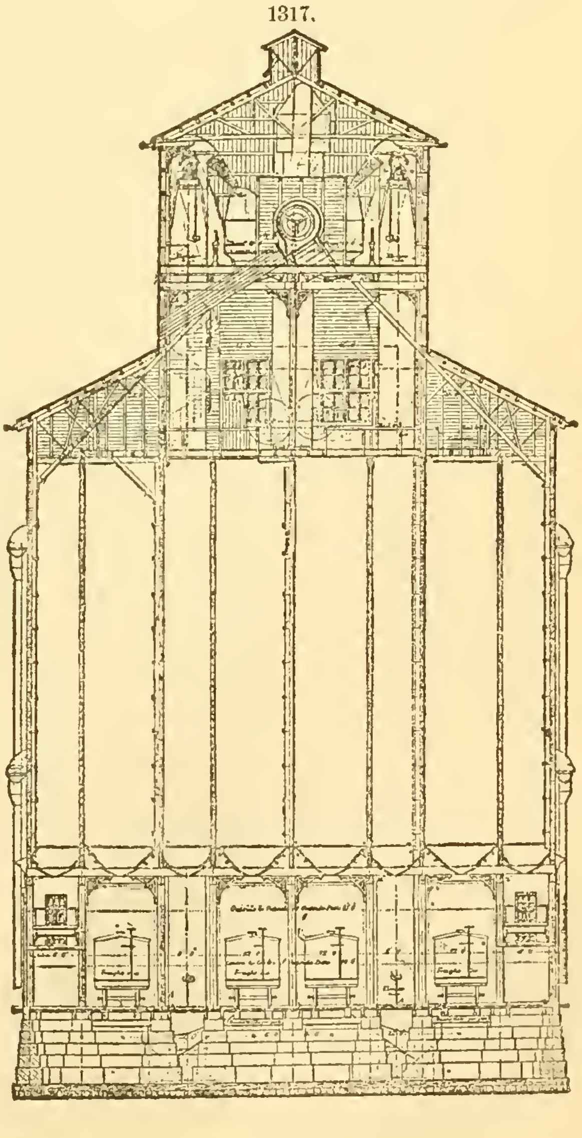
the cylinder. The frame $a$ $a$, Figs. 1310 and 1311, is composed of upright standards and cross-bars, whose joints are, for the sake of durability, covered with iron bands. The nine vertical beams $b$ $b$ $b$ form in the plan four equal squares, Fig. 1312. They rest on cast-iron pedestals $c$ $c$, Figs. 1310 and 1311, into whose holes they are firmly fixed by means of wooden wedges. In two of the squares, by the side of each other, the iron ore and other materials are drawn up in vessels or tubs $A$ $A$, one of which is represented in Fig. 1312. The vessels are provided with two cast-iron crosses, $d$ $d$ and $e$ $e$, joined by the wrought-iron bars $f$ $f$. The cross-arms form diagonals of the squares, and are at their ends provided with rollers $g$ $g$ $g$ $g$, grooved at their periphery to fit the rectangular rails $h$ $h$ $h$ $h$, on which they run up and down from the bottom to the top of the elevator. The vessels containing the ore, etc., are placed on the iron plate $i$ $i$ resting on the lower cross. The square marked $k$, Fig. 1312, is the upper face of a pedestal. To each of the frames are fixed the chains $l$ $l$. The other ends of the chains pass round the cast-iron wheel $m$ $m$ and are fastened. The wheels are fixed on the shaft $n$ $n$, to the middle of which a third wheel $o$ is attached, of far smaller diameter than that of the other ones, and to whose periphery is fixed the chain $p$ $p$, fastened at its lower end to the joint-head $q$ of the piston-rod $r$. The piston $P$ moves up and down in the air-cylinder $s$ $s$, which is about 10 feet high, 2 feet in diameter, and open below. The piston-rod is packed as in a steam-engine. At the side of the cylinder is the valve-box $u$, Fig. 1311, which receives the condensed air from the reservoir of the blast apparatus through the pipe $v$ $v$, and from which again it can be let into the cylinder $s$ $s$, by means of the valve $w$. The valve is hollow, to permit the escape of the condensed air (after it has pressed down the piston to the extremity of the cylinder) through the aperture $x$. As soon as the valve $w$ is moved out of its position, as shown in Fig. 1311, downward (which is effected by the combined contrivance of the bar $\alpha$, the shaft $\beta$, and the lever $\gamma$), the condensed air acts on the piston $t$ and presses it down. The effect of this is that the vessels $A$ $A$ are drawn up simultaneously with a velocity surpassing the movement of the piston in proportion to the difference in diameter between the wheels $m$ $m$ and the wheel $o$. As soon as the vessels are lowered again, the slide $w$ is drawn upward; and as the condensed air filling the cylinder escapes through the aperture $x$, the vessels $A$ $A$ sink by their own weight, which surpasses that of the counterbalance $P$. The piston $t$ is at the same time drawn up to the upper part of the cylinder.

*Elevator for raising bricks, mortar, and any other materials employed in building, and adapted to the unloading of ships and warehousing of goods*, Figs. 1313 to 1316.—The main part of the machine $A$, consisting of the gearing to set the machine in motion, rests upon the ground. The second part is a trestle, which may be placed upon the scaffolding of the bricklayers, as at $F$; in the upper part of this trestle is an indented wheel $B$, which corresponds perpendicularly with a similar wheel, attached to the principal body of the machine, resting on the ground. Passing round these two wheels is an endless iron chain, which is put in motion by one or several men, who turn the handle of the machine $A$, consisting of a pinion-wheel working into a large toothed wheel, on the axis of which is an indented wheel, round which an endless chain passes, and also round a corresponding wheel at the side of the one at the foot of the vertical chain; the latter is set in motion when the lower wheel revolves, together with the endless chain just described, over the indented wheels at $C$ and $E$, by which the chain operates its rotation. On the side of the chain ascending the workmen attach their hods full of materials by means of a hook fixed in the hod, as at $B$, and others detach them, as at $F$, to carry them to the bricklayers on the scaffolding. The empty hods are attached to the chain on the opposite side, as at $G$, and descend to the ground, where they are detached, as at $H$. The chain may be lengthened and shortened as necessary. When a story is added to the scaffolding, the trestle is placed upon the new story, and the chain lengthened as required. At the top is a screw for tightening or relaxing the chain, as occasion may require. In Fig. 1316, $I$ $K$ $L$ are accessories used for hoisting the materials, viz.: $I$ for broken bricks, $K$ for water, and $L$ for pieces of stone for windows, chimneys, etc. Fig. 1314 is an enlarged view of the indented wheel, and Fig. 1315 of the chain.

For elevators and other hoisting apparatus used in mines, see Mine Appliances. For grain elevators, see Elevators, Grain. For ice elevators, see Ice-Harvesting Apparatus. T. S. (in part).

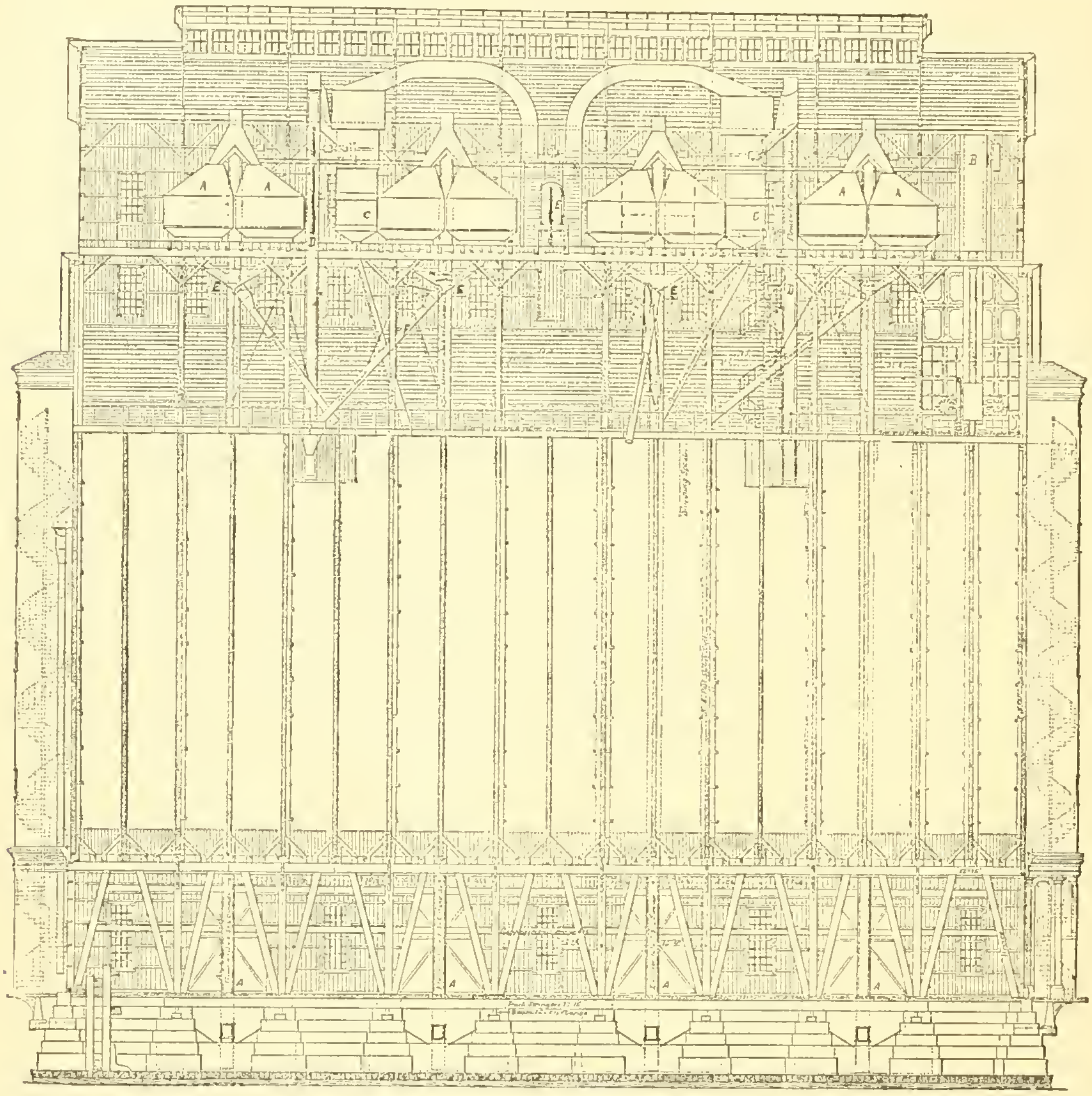
ELEVATORS, GRAIN. In this country the name of grain elevators is given to certain establishments in which the transshipment of grain is carried on, and in which it is often stored for long periods. The grain is weighed when taken in, and

1317.



again when sent out. The removal of the grain from one spot to another, necessitated by these operations, is almost wholly effected by machinery in a very small space and in a very little time. There are establishments capable of storing from 1,000,000 to 1,500,000 bushels of grain at once, and these may take in from 5,000 to 8,000 bushels an hour, and send out twice that quantity in

1318.



the same time. If it be borne in mind that the distinctions of shipper, receiver, and owner have to be kept up, it will be seen that the problem solved by the grain elevator is a very complicated one. The buildings are approachable by vessels upon one or more sides, and have tracks for railroad cars running into them on a level with the adjoining ground. The grain is shoveled from the cars into receiving pits, from which it is raised by buckets attached to an endless belt to the upper part of the building. In order to weigh it, it is stopped at the beginning of its downward motion in a hopper resting upon a scale. To clean it, it is let fall from the top of a cylinder 15 or 20 feet long, up which a strong current of air is driven by a fan. The grain is stored in compartments, or bins, into which the building is divided, which are generally about 10 feet square and from 50 to 65 feet deep. The bottoms of these bins are hopper-shaped, in order that the grain may run out of its own accord through an orifice of limited section. A small annex to the principal building contains the engine and boilers. The motion is transmitted by belts to one or two horizontal shafts in the upper part of the building, which drive the elevators. Such are the general arrangements of an elevator building.

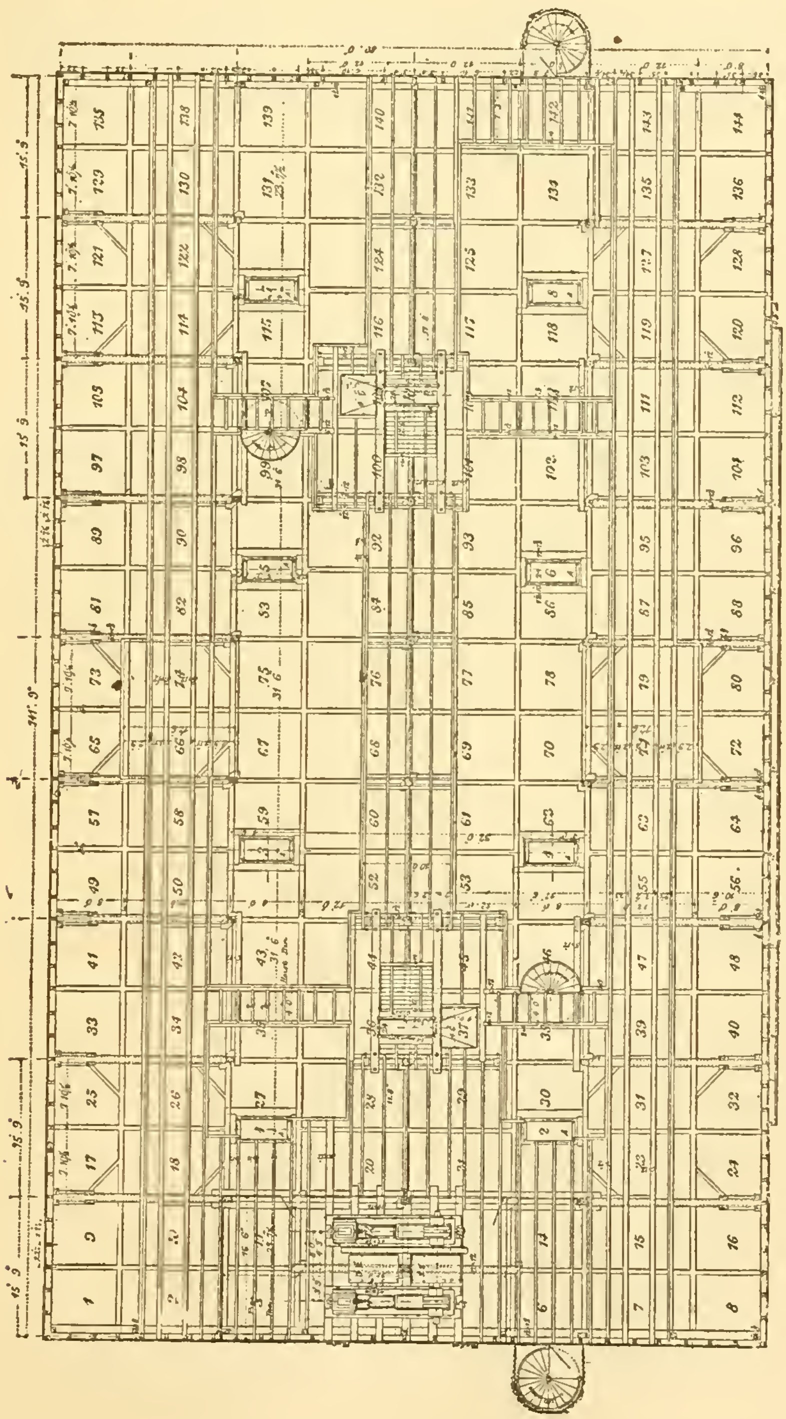
As an example of improved construction of grain elevators, elevations and plan of the Canton elevator are presented in Figs. 1318, 1319, and 1320.* The structure is located at Canton, near Baltimore, Md., and is built upon a pier 100 feet in width, which extends into the bay for a distance of 500 feet from low-water line. The foundation is of piling 60 feet long, spaced about 2 feet from centre to centre, and cut off at 3 feet under extreme low water. Around these piles were driven two rows of sheet-piling, and the whole space filled with oyster-shells and small stones, forming a solid foundation of great strength and stability. Upon the tops of the piles was laid a platform 151 feet long and 85 feet wide, formed of two thicknesses of 12- by 12-inch Georgia pine. This was of sawed timber laid close, and well secured by rag-bolts and locust treenails. The principal dimensions of the superstructure are given in the following table, and will serve as a guide to indicate relative proportions in designing buildings of similar character:

* *Engineering*, xxii., 571.

| | Feet. | Inches. |
|---|---|---|
| Length from outside to outside of posts | 142 | 11 |
| Width " " " at base | 81 | 0 |
| " " " " on weighing floor | 40 | 8 |
| Height from masonry to top of main rafters at centre | 139 | 6 |
| " " " to under side of grain-bins in clear | 19 | 5 |
| Thence to top of grain-bins | 62 | 4 |
| " to under side of next floor-beam, | 25 | 0 |
| " to top of wall-plate | 21 | 8 |
| " to top of main rafter | 11 | 1 |
| Ventilating top upon main roof adds | 6 | 0 |

There are 144 rectangular bins; one is used for piping and one for a hoisting pit, leaving 142 for grain. One-half of the number measure 7 feet 4½ inches by 7 feet 6 inches by 60 feet inside, excepting where each elevating tube passes through the bins, in which case a partition is cut out,

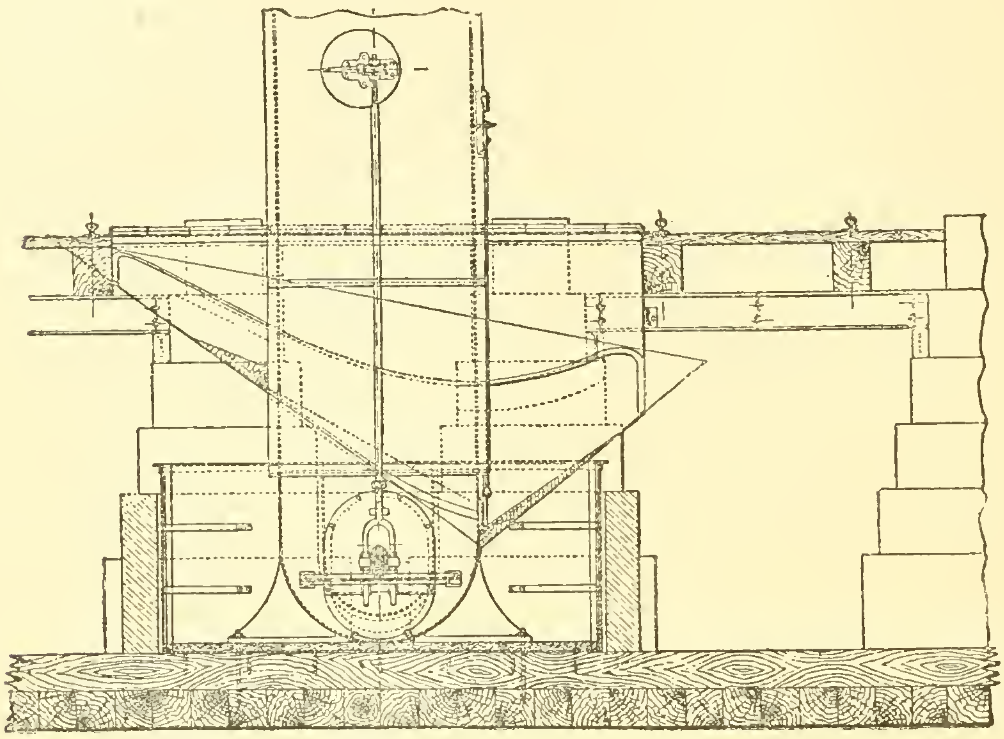
1319.



making a bin 15 feet 3 inches by 7 feet 6 inches by 60 feet inside. The engines are located above the grain-bins at the land end of the building; they are horizontal, with two cylinders 16 inches in diameter and 24 inches stroke. A piece of 4-inch gas-pipe, supported by bearings, extends through the centres of all elevator tubes in each line, and receives from the main engines a horizontal movement of 12 feet and about 14 double strokes per minute. To this gas-pipe, at each elevating tube, two large scoops or shovels are attached by ropes passing through leaders properly arranged; by

means of these the cars are quickly unloaded. The centre line of shafting passes through the centre of elevating tubes, and at each tube it has a paper friction-pulley, 1 foot 6 inches in diameter, built of disks of best quality of Manilla paper, under a pressure of 60 tons, and secured by heavy followers and bolts. Above each paper friction-pulley is one of cast-iron, double-armed, very heavy, 3 feet 9 inches in diameter and 22 inches face; it has adjusting machinery attached to its short

1320.



shaft. In the boot at the base of the elevator is a drum-pulley 2 feet 6 inches in diameter, 22 inches face, fitted with stretching gear for the belt, and worked from the track floor. The grain-belt is of rubber, four-ply, 20 inches wide; it connects these two last-mentioned pulleys, and is kept tight by the stretching gear just mentioned. The grain-buckets, of heavy tin, are spaced 12 inches from centre to centre, and secured to the belt by six bolts in each bucket. They measure 18 inches long, 5½ inches deep, 6½ inches wide. The shafting being in motion, the upper belt-pulley is lowered, and rests upon the paper friction-pulley, thus causing the elevating belt to travel at about 450 feet per minute. In front of each elevator tube are placed two sets of Fairbanks scales, each fitted with an iron tank, having cylindrical body, conical top and bottom, with capacity for 540 bushels of wheat, shoot-spout and valve fitted to the bottom of weighing tank. Under each pair of tanks is a conical collecting hopper, having a crane-spout leading from it to the storage bins, shifting conveyer, or shipping spouts, as desired. Two shifting conveyers are located, as shown in section, above the grain-bins, and extend the whole length of the building. They consist of four-ply rubber belts, 30 inches wide, supported by wooden rollers, spaced 5 feet apart under the loaded and 10 feet apart under the unloaded belt. They are driven by bevel friction-gear of paper, and are reversible. They move at a speed of 550 feet per minute, and are arranged to throw off the grain wherever desired. The belt is perfectly flat, has no raised edges, and does not spill any grain when working under a capacity of 9,000 bushels per hour. The arrangement of crane-spouts is fully explained by the drawings.

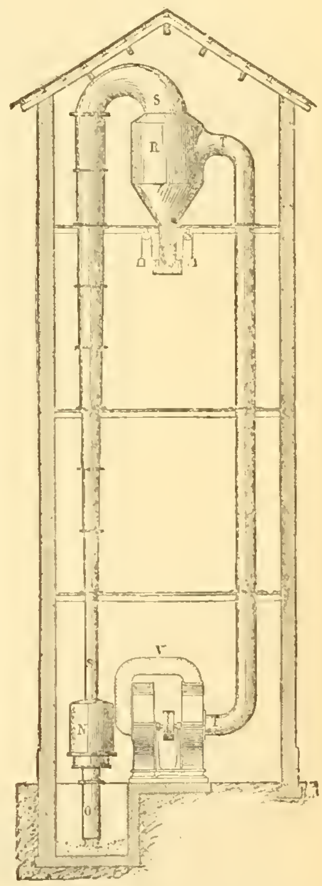
The working of each line of elevators is as follows: Four cars of grain having been passed by the inspector are pushed in upon one track, until stopped by the bumper at the end, which will leave the doors nearly opposite the elevators. The car doors having been opened, two attendants enter each car with the wooden shovels, with which they quickly discharge the grain into the receiving hopper. The ropes which work the scoops are attached so as to work alternately, this causing a continuous flow of grain through the door of the car, so long as any remains or the gas-pipe plunger is kept in motion. At the beginning of this operation the grain-valve in the boot, Fig. 1320, should be opened, so as to allow the grain to flow from the receiving hopper into the ascending belt-buckets (all of the machinery being in operation) just fast enough to fill them.

The grain is discharged from the head of the elevator into one of the weighing tanks, where the whole car-load is collected, weighed, and distributed. While this operation is in progress, four cars are pushed in on the other side of the same elevators and discharged in the same manner, as soon as the valve at the elevator head is shifted to the other weighing tank, which is done after all of the first lot is raised. The first line of empty cars is now drawn out and full ones take their places, and this operation is repeated as rapidly as circumstances will allow. The weighing tank having been filled, the grain is weighed and discharged through the valve into the collecting hopper and crane-spout, to where it may be required. The crane-spout is made of sufficient size to deliver the grain much faster than the elevator can lift, so that one weighing tank may always be ready to receive grain. The crane-spout can deliver the grain into each of many storage-bins, shipping bins, shipping spouts, or shifting conveyers, as may be desired or found necessary. Should all the elevators be

working one kind or lot of grain to be stored in one part of the house, the crane-spouts which can reach those bins may be used, and the remainder of the grain be discharged upon the shifting conveyers, and by them placed in the bins. Similar use is often made of shipping conveyers when working the whole house upon one vessel, or a single elevator upon a large vessel which cannot be moved, the elevator being a long distance from the spout leading to the vessel. Should a vessel be nearly ready for grain or be taking bagged grain, it is run into the shipping bins, and from them drawn off as required. When the grain in the house or storage bins is to be shipped, spouts are attached to the bottom of the bins, and the grain discharged into the receiving hopper in a continuous stream, elevated as before described, weighed at the top of the house, and discharged through crane and shipping spouts into the ship.

When grain is ordered for clean delivery, it is elevated in the regular way, weighed, and discharged into the foot of the cleaning elevator, by which it is lifted to the top of the house and delivered into a feeder. From the feeder it flows on to a screen made of perforated Russia iron, measuring 8 feet wide by 12 feet long, and is set at an angle of 25° from horizontal; it is driven at a speed of 1,100 vibrations per minute. As the grain falls upon it, the cobs, sticks, straws, etc., are carried over the end; the grain passes through and down an inclined plane to a wind-spout 8 feet by 1 foot, where it is met by a strong current of air. The unsound grain, dirt, and chaff are carried off, and the cleaned grain falls into a chamber, and is carried where desired by an iron pipe. The unsound grain is deposited in the dirt room, and the chaff and light dirt thrown into the water. The current of air is produced by a large exhaust fan. As only about 10 per cent. of the grain goes through the cleaner, it is claimed that this system of "cleaning elevators" for lifting the grain to be cleaned is a great improvement upon the custom of building the house high enough for the cleaner, and raising all of the grain to that height, whether it has to be cleaned or not. A saving of 10 per cent. in fuel is claimed by this arrangement. Each of these machines will draw grain from four main elevators, and clean 8,000 bushels per hour.

1321.




The total storage capacity of this building is 500,000 bushels. The total elevating capacity per hour is 32,000 bushels. The size of the grain-bins depends upon the nature of the business, location, rules of produce exchanges, and systems of grading. Small ones in larger numbers are the most convenient, as many prefer their grain separate. With heating grain they save loss, and where there is no grading of grain they are necessary.

*The Renhaye Elevator*, Fig. 1321.—The principle on which this apparatus is based is, that when divided solid matters are mixed with air in motion in a conduit, a semi-fluid is formed, in which the pressures vary according to the laws of ordinary fluids. It may be demonstrated mathematically that in the semi-fluid column pressures vary as in ordinary fluid; that the specific weight of the semi-fluid column may augment up to a certain limit; that the solids may be elevated to any height by regulating the specific weight of the semi-fluid according to the pressure obtained; that when the specific weight of the semi-fluid column is too considerable in proportion to the pressure, this column attains a limit in height which it cannot pass; and that the maximum results take place when the specific weight of the semi-fluid column is in the neighborhood of its maximum. Barret and Korting have both utilized air-pressure as a means of elevating grain, the one employing the vacuum produced by an air-pump, the other entraining the air by a steam-jet. The Renhaye elevator differs from both of these in that the air is set in motion by a fan-blower or centrifugal ventilator, and that the specific weight of the semi-fluid is regulated by a pneumatic regulator. $V$ is a double ventilator capable of giving a pressure equivalent to 29.2 inches of water, connected to the receiver $R$ by the tube $T$. Into the receiver $R$ the grain passes by the tube $S$, which is separated from the tube $T$ by a plane inclined at 45°, which carries the grain to the lower part of the chamber. In the upper portion of the latter is a perforated partition which affords passage to the air and to dust. The grain escapes at the lower portion upon a platform placed at suitable distance to regulate the escape and hinder the reëntry of air. $N$ is a regulator which governs the weight of the semi-fluid column according to the pressure; it consists of a piston, the joint of which is a rubber membrane which extends without friction. A tube connects the tube $S$ with the lower portion of the regulator. The piston is connected by pulleys with a damper $O$, which comes down over the lower end of pipe $S$, and is designed to admit more or less air into the semi-fluid mass. The quantity of air is by means of the piston regulated according to the pressure of the ventilator. It will be obvious that if the exhaustion of air in $S$ reaches too high a degree, the upper part of $N$ descends and $O$ is thus drawn up, increasing the air orifice at the bottom of the pipe.

MM. Sautter and Lemonnier have made numerous experiments on this device, of which the following are some of the results: The receiver was placed 32 feet above the ground. The motive power was 6-horse to elevate from 17,500 to 22,000 lbs. per hour, and the regulator worked perfectly the instant the lower orifice of the pipe became choked. A large quantity of dust was mixed with the grain, but the latter was delivered perfectly clean, the impurities passing off through the aspirating pipe. By taking out the receiver and leading the grain through the ventilator, the material was cleanly cracked without production of flour. To secure the best results it has been found that the velocity of the solids on arriving in the receiver should be nothing, and that the velocity of the air

leaving the ventilator should have a determined value for each kind of grain. The rising tube is gradually increased in diameter so as to diminish progressively the velocity of the grain as it approaches the receiver. The latter is constructed so as to divide the air-current by means of numerous concentric rings, and the orifice of the aspiration tube is enlarged so as to diminish the strangulation of the fluid vein. At the lower part of the escape tube is placed a conical counterweighted regulator. The regulator is placed around the rising tube, and is in communication with the air passing from the ventilator, and hence modifies the velocity of the entrained air. This arrangement is said to give results far in advance of those reached by any other pneumatic system of elevation. It has been determined by experiment that by giving the air a velocity of circulation of 64 feet per second, grain, plaster, and similar substances can be elevated in a vertical tube; with a velocity of 128 feet, stone in pieces large enough for macadamizing may be lifted; with a velocity of 192 feet, heavy bodies, such as leaden balls, pieces of iron, etc., can be elevated. Large spikes, screw-bolts, coke, coal, and iron chain have been thus lifted without difficulty.

Fig. 1322 represents a simple form of elevator for unloading vessels. The extremity of the shoot *C* is inserted in the hold of the vessel about to be discharged, its height being regulated by the

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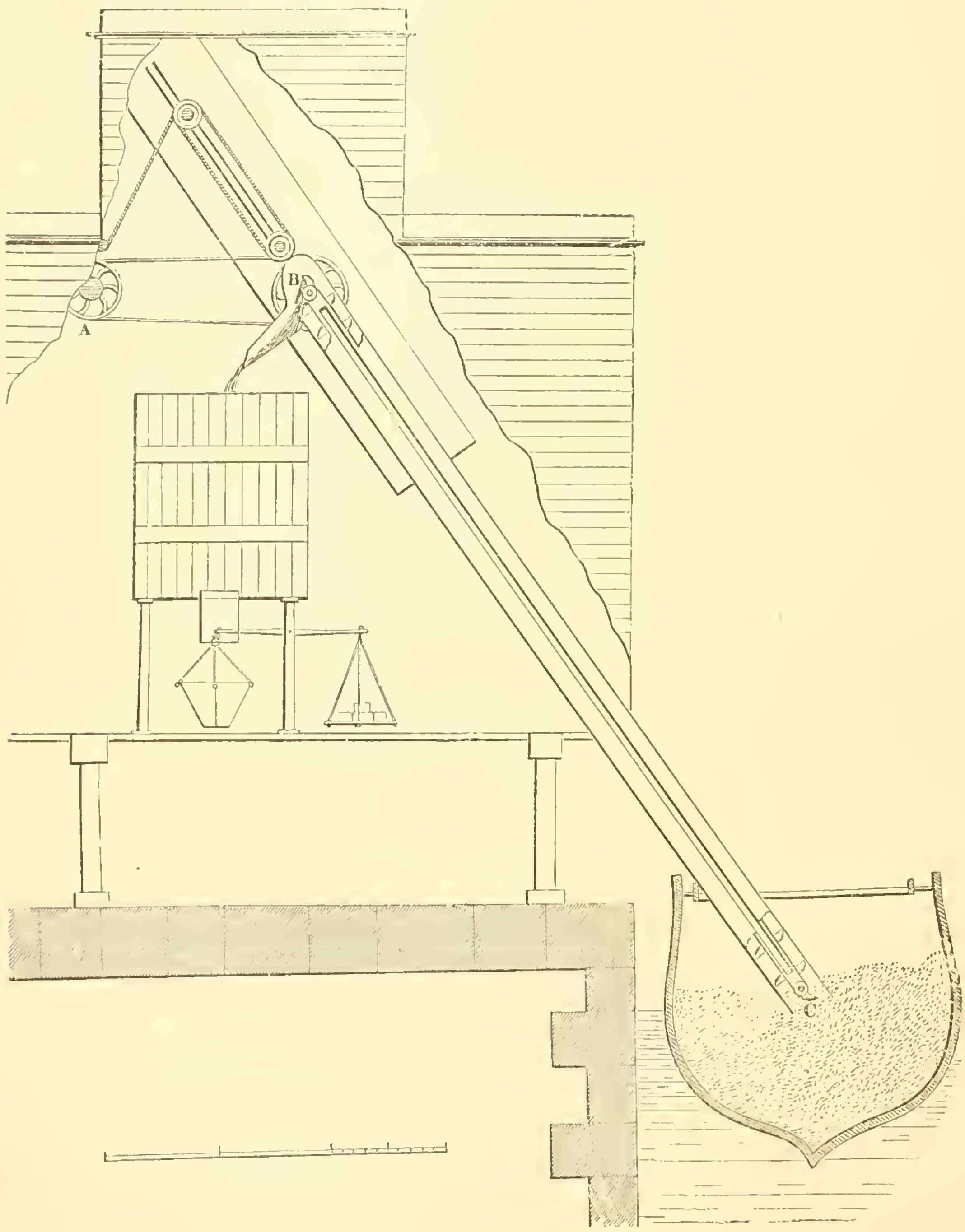
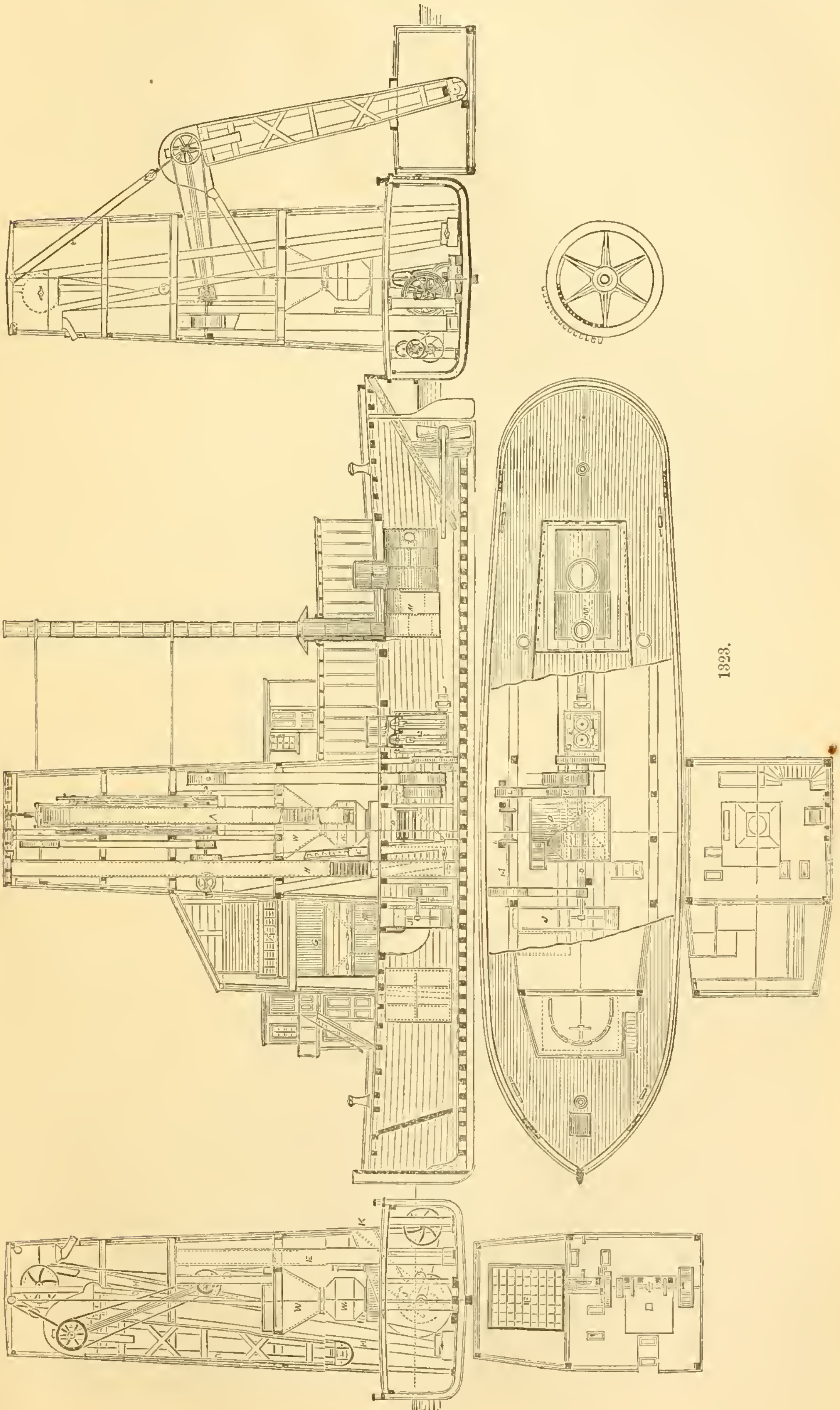



guide-frame and pulleys. The machine is put in motion by means of the prime mover *A* and band-wheel *B*, when by means of a series of tin dippers attached to a belt of gutta-percha or leather, tightly stretched over the wheels at *B* and *C*, the grain is brought up to a height of 76 feet, and discharged by means of the small spout attached to the elevator into the weighing machine; from thence, by a repetition of the same contrivance, it is taken through the building to a shoot on the roof, containing an Archimedean screw, by the use of which and the elevator the grain may not only be placed on any particular floor in the warehouse, but may be transshipped.

*Floating Elevator.*—Figs. 1323 to 1326 are a plan, cross-sections, and longitudinal section of a floating elevator designed by Messrs. Gill & Mansfield of New York. This kind of elevator is used for transferring grain from one vessel into another. By means of them, ships can take their con-

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signment of grain while lying in their docks and receiving the rest of their cargoes; avoiding thereby the expense of moving to a storage elevator, as well as the expense of storage, as grain coming into port by boat can be immediately transferred to the vessel to which it is consigned.

The vessel carrying the elevator is constructed on the ordinary propeller model. The one here described is 100 feet long on the keel, with 10 feet depth of hold and 27 feet breadth of beam amidships. The propelling power is furnished by an engine of 150 horse-power. The engine is arranged so as to be disconnected from the propelling apparatus when its service is required for elevating purposes. Only 35 horse-power is required to work the elevator up to its full capacity, i. e., elevating, cleaning, and transferring 5,000 bushels per hour. In the figures, *A* is the boat elevator; *B*, the yoke in which the boat elevator hangs; *C*, a telescopic spout, which is lengthened or shortened as the boat elevator is lowered or raised into position; *D*, a receiver or pit; *E*, the screen elevator; *F*, the screen; *G*, the wind-spout; *H*, the shipping elevator; *I*, the shipping spout; *J*, the fan; *K*, an outlet for the dirt blown out of the grain; *L*, the engine—a surface condenser with two 18- by 18-inch cylinders.

The position of the elevator when transferring grain is naturally between the two vessels. The boat elevator is lowered into the hold of the vessel containing the grain, by means of a rope attached to the drum *F*. The grain, being raised by the elevator *A*, passes downward through the spout *C* into the receiving hopper *W*, from which by means of a valve portions of it are drawn off from time to time into the weighing hopper *W'*. From this, after being weighed, it is passed into the receiver *D* to the foot of the screen elevator *E*, by which it is again raised and passed down over the screen *F* (an inclined, perforated sheet of Russia iron) into the wind-spout *G*, where it is met in its descent by a strong current of air caused by the fan *J*. By this current of air all the chaff and foreign matter in the grain is driven out through the outlet *K* into the river, the grain falling to the foot of the shipping elevator *H*, by which it is again raised and passed out through the shipping spout *I* into the vessel alongside.

EMERY-GRINDING. Emery-wheels are employed mainly for producing cutting edges and for smoothing surfaces. Their action is abrasive, and is termed grinding or polishing, according to the nature of the duty. It is indeed somewhat difficult to separate the grinding from the polishing duty, as the end to be attained rather than the nature of the duty determines the name by which that duty is known. As a general rule, however, emery polishing wheels are distinguished from grinding wheels in that the former are composed of wooden disks covered with leather, the surface of which is covered with emery fastened thereon by glue; while the grinding wheels are composed of emery and cement. As a matter of fact, the action of the emery is merely abrasive in both cases; and although in practice wheels composed of, or covered with, the finer grades of emery (that is to say, from about No. 70 to No. 120) are used for polishing purposes, yet, as before stated, emery polishing wheels are understood in our workshops to be wheels of wood covered with leather and coated with emery. Notwithstanding this, however, wooden wheels are sometimes coated with emery of the coarsest grades (from about No. 10 up to No. 50), and the action of such wheels can scarcely be properly termed that of polishing. The duty of solid emery-wheels, composed of even the finest grades of emery, is usually termed emery-grinding, although the result attained is in many cases that of coarse primary polishing.

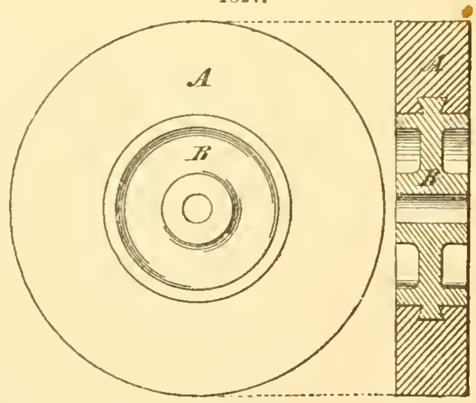
The solid emery-wheel is an American invention, and has in the smaller sizes attained great prominence of late years from its special capabilities; such, for instance, as the grinding of hardened tools or cutters to a true edge, or of hardened surfaces to a true conformation. The larger sizes of solid emery-wheels are used for purely abrasive or grinding purposes, for which the fast-running grindstone is either too unwieldy, or so obstructive to the workman's operations as to render the manipulation both tedious and crude. Among this class of operations may be enumerated the grinding of ploughshares, stove-plates, and wrought-iron plates, the fettling of iron castings, and the grinding of the inner surfaces of hollow iron ware. In all the latter classes of work, however, the emery-wheel has displaced the grindstone because of its handier and greater adaptability to the size, shape, and form of the works, rather than to its cutting qualification. For it is an indisputable fact that, while the speed at which an emery-wheel can be run is several times greater than that at which it is safe to run a grindstone, yet a large grindstone will remove a given quantity of metal in less time than any emery-wheel, even of the largest sizes yet made. Another and very successful field of operations occupied by the solid emery-wheel is that of finishing work in the lathe. Thus, the bearings of spindles and the surfaces of steel or chilled cast-iron rolls may be and are finished more true and given a finer polish by emery-wheels than is possible with lathe tools of any kind whatever.

In all cases of the employment of emery-wheels in place of steel cutting tools, the operation is considerably slower, and it may be laid down as a rule that, save upon metal too hard to be operated upon by steel tools, the emery-wheel cannot compete with the ordinary lathe, planer, or milling-tool. And furthermore, the emery-wheel cannot compete with the planer or with the file in the production of flat surfaces upon either hard or soft metals. Indeed, as a fitting-tool for fine work, the emery-wheel, except upon cylindrical surfaces, is out of place. In the abrasive operations carried on in the manufacture of needles, cutlery, harness-hardware, etc., the emery-wheel is a most valuable tool, and has assumed a very important position. This is largely due to its strength in proportion to its shape and size. For instance, vulcanite emery-wheels 18 inches in diameter, and having three-sixteenths of an inch thickness (or "face," as it is commonly termed), are not unfrequently used at a speed of some 5,000 feet (measured at the circumference) per minute; whereas it would be altogether impracticable to use a grindstone of such size and shape, because the side pressure would break it no matter at what speed it was run. Indeed, in the superior strength of the emery-wheels of the smaller sizes lies their main advantage, because they can be made to suit narrow curvatures, sweeps, recesses, etc., and can be run at any requisite speed under 5,000 feet per minute, and with considerable pressure upon either the circumferential or radial faces.

The distinctive feature of the various makes of solid emery-wheels lies in the material used to cement the emery together, and much thought and experiment is now directed to the end of discovering some cementing substance which will completely fill all the requisite qualifications. Such a material must bind the emery together with sufficient strength to withstand the centrifugal force due to the high speeds at which these wheels must be run to work economically; and it must neither soften by heat nor become brittle by cold. It must not be so hard as to project above the surface of the wheel; or in other words, it should wear away about as fast as does the emery. It must be capable of being mixed uniformly throughout the emery, so that the wheel may be uniform in strength, texture, and density. It must be of a nature that will not spread over the surface of the emery, or combine with the cuttings and form a glaze on the wheel. This glazing is in fact one of the most serious difficulties to be encountered in the use of emery-wheels for grinding purposes, while it is a requisite for polishing uses, as will be explained further on. Many of the experiments to prevent glazing have been in the direction of discovering a cement which would wear away under about the same amount of duty as is necessary to wear away the cutting angles of the grains of emery, thus allowing the emery to become detached from the wheel, rather than to remain upon it in a glazed condition. In the following list of cementing materials in common use, the initial W. prefixed signifies that the wheel thus made may be used with water; H., that the wheels are compressed by hydraulic pressure; and T., that they are tamped: W. H. Hard rubber. H. Chemical charcoal; that is, leather acted upon by acid (used to prevent shrinkage) and glue. T. Oxychloride of zinc. W. H. Shellac, linseed oil, and litharge. T. Silicate of soda (water-glass) and chloride of calcium; celluloid. T. Oxychloride of magnesia. W. H. Infusoria. H. Pure glue.

The speed at which an emery-wheel may be run without danger of bursting varies according to the thickness or breadth of face of the wheel, as well as according to the quality of the cementing material and excellence of manufacture. Hence, although a majority of manufacturers recommend a speed of about 5,000 circumferential feet per minute, that speed may be largely exceeded in some cases, while it would be positively dangerous in others. It is in fact impracticable in the operations of the workshop to maintain a stated circumferential speed, because that would entail a constant increase of revolutions to compensate for the wear in the diameter of the wheel. Suppose, for example, that a wheel when new is a foot in diameter: a speed of about 1,600 revolutions per minute would equal about 5,000 circumferential feet; whereas, when worn down to 2 inches in diameter, the revolutions would require, to maintain the same circumferential speed, to be about 9,500 per minute, entailing so many changes of pulleys and counter-shafting as to be impracticable. In practice, therefore, a uniform circumferential speed does not exist, the usual plan adopted being to run the large-sized wheels, when new, at about the speed recommended by the manufacturer of the kind of wheel used, and to make such changes in the speed of the wheel during wear as can be accomplished by changing the belt upon a three-stepped cone-pulley, and perhaps one, or at most two, changes of light pulley upon the counter-shaft. It is sometimes practicable to use wheels of a certain diameter upon machines speeded to suit that diameter, and to transfer them to faster-speeded machines as they diminish in diameter. Even by this plan, however, only an approximation to a uniform speed can in most cases be obtained, because as a rule certain machines are adapted to certain work, and the breadth of face and form of the edge of the emery-wheel are very often made to suit that particular work. Furthermore, a new wheel is generally purchased of such a size, form, and grade of emery as are demanded by the work it is intended at first to perform. Neither is it as a rule practicable to transfer the work with the diametrically reduced wheel to the lighter and faster-speeded grinding machine. So that, while it is desirable to run all emery-wheels as fast as their composition will with safety admit, yet there are practical objections to running small wheels at a rate of speed sufficient to make their circumferential velocities equal to those of large wheels. The speeds recommended for the various kinds of wheels now in use vary from about 2,700 to 5,600 circumferential feet per minute; but the speeds obtaining in workshops average between 2,000 and 4,000 feet for wheels 3 inches and less in diameter, and from about 3,000 to 5,600 feet for wheels above 12 inches in diameter. Wheels above 15 inches in diameter, and of ample breadth of face, are not unfrequently run at much greater velocities.

1327.




Emery-wheels should be held upon their driving-spindles by the flanges upon the face; for if the bore of the wheel fits tightly upon the driving-spindle or arbor, and the latter should become heated, its expansion would tend to burst the wheel. To prevent this, and to permit the wearing out of the wheel without excessive variation in the circumferential speed of the wheel as the wear takes place, the vulcanite wheels *A* above 14 inches in diameter are made upon a cast-iron centre, as shown at *B* in Fig. 1327. The spindles or arbors for emery-wheels should have a solid arbor for the wheel to jam against, and a washer and nut on the other side. The thread should be such that the resistance upon the washer shall be in a direction that will tend to screw up and not unscrew the nut; otherwise the latter will be apt to become loosened. It is obvious, therefore, that where an arbor drives two wheels, it will require a right-hand thread upon one and a left-hand thread upon the other end. When the wheel is composed entirely of emery, that is to say, when no metallic centre is used, it is an excellent plan to place between the collars and the side of the wheel a leather or other suitable washer; and in this case the inside face of the collars may be made slightly hollow, so as to insure that the surface most firmly gripped shall be that at the outer diameter of the wheel. This will

tend to secure its truth as well as to maintain the grip. If the wheel requires to be taken on and off the arbor occasionally, it is well to bore the hole in the wheel enough larger than the size of the arbor to admit of a lead ferrule being put into the wheel, and then bored out to give the arbor an easy working fit. In no case must a key or feather be employed, because it tends to destroy the balance of the wheel.

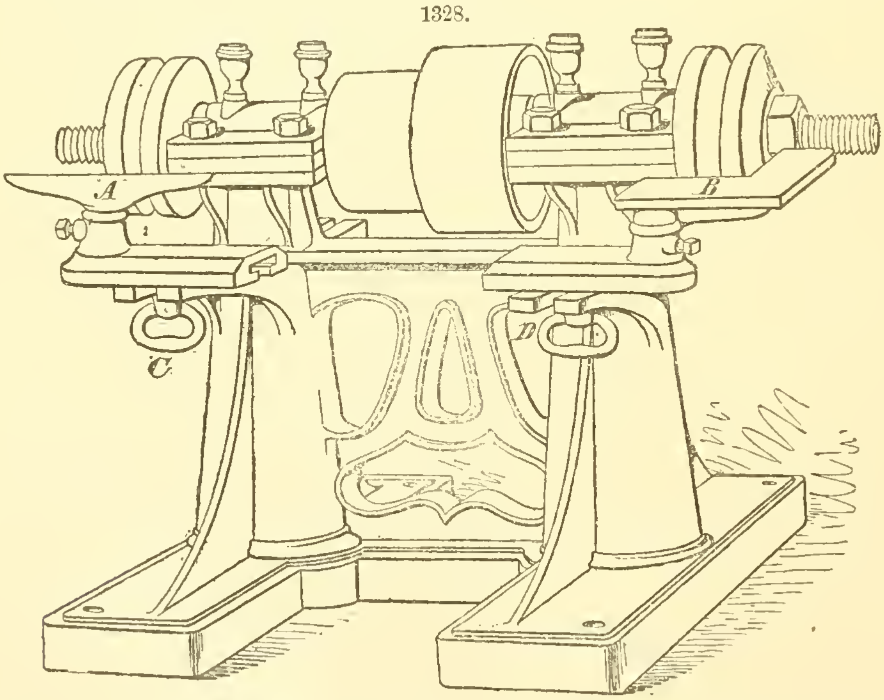
The balancing of emery-wheels is a very important element; for, unless the wheel itself as well as the arbor and driving-pulley be properly balanced, the great velocity of the wheel will cause vibrations which will mark the work very plainly. Messrs. Morton, Poole & Co., of Wilmington, Delaware, found that the difference in the density of cast-iron arbors moulded horizontally was sufficiently great to mar considerably the smoothness of the grinding operations for which that firm have become famous. Hence all their arbors, pulleys, etc., are cast vertically, and with gates of sufficient height and body to insure solidity in the castings. Each piece is separately balanced, and the balancing process is repeated as each part is assembled. Even with all these precautions, however, it is impracticable to secure in all cases perfect truth as well as balance, especially in the wheels themselves, because of the difficulty of securing a sufficiently uniform density. Hence, for accurate work performed at high velocities, it is found to be preferable to turn up the perimeter of the wheel true, and to vary the thickness of the wheel on diametrically opposite sides when that is necessary to balance it. It will not answer to turn the emery-wheel true and balance it through the medium of the arbor, pulley, or collar; because in that case, though the whole may be balanced at first, the balancing will be destroyed as the diameter of the wheel diminishes. The best method of operating upon the wheel to balance it is so to adjust the centres of the arbor, or apparatus upon which it is turned, as to throw the side face of the wheel out of true to an amount just sufficient to allow the face to true up when the wheel is balanced, taking very light cuts and trying the balance after each cut. The tool employed to turn emery-wheels is the bort or black diamond, held in an iron stock or holder. Being easily broken, it must be brought to bear gradually and not violently against the work.

The grades of emery used for solid emery-wheels, and the smoothness of the duty as compared to files, are as follows:

| No. of Emery. | Grade of Cut. | No. of Emery. | Grade of Cut. |
|---|---|---|---|
| 8 to 10 | Wood rasp. | 46 to 60 | Second-cut file. |
| 16 to 20 | Rasp file. | 70 to 80 | Smooth file. |
| 24 to 30 | Rough file. | 90 to 100 | Superfine file. |
| 36 to 40 | Bastard file. | 120 | Dead-smooth file. |

*Emery-Grinders.*—The machines in which solid emery-wheels are used are termed emery-grinders; and of these there are various kinds designed to suit various classes of duty. For general work the class of machine represented in Fig. 1328 is employed, the rests *A* and *B* being adjustable and secured in position by means of the hand-screws *C* and *D* respectively. This class of grinder is

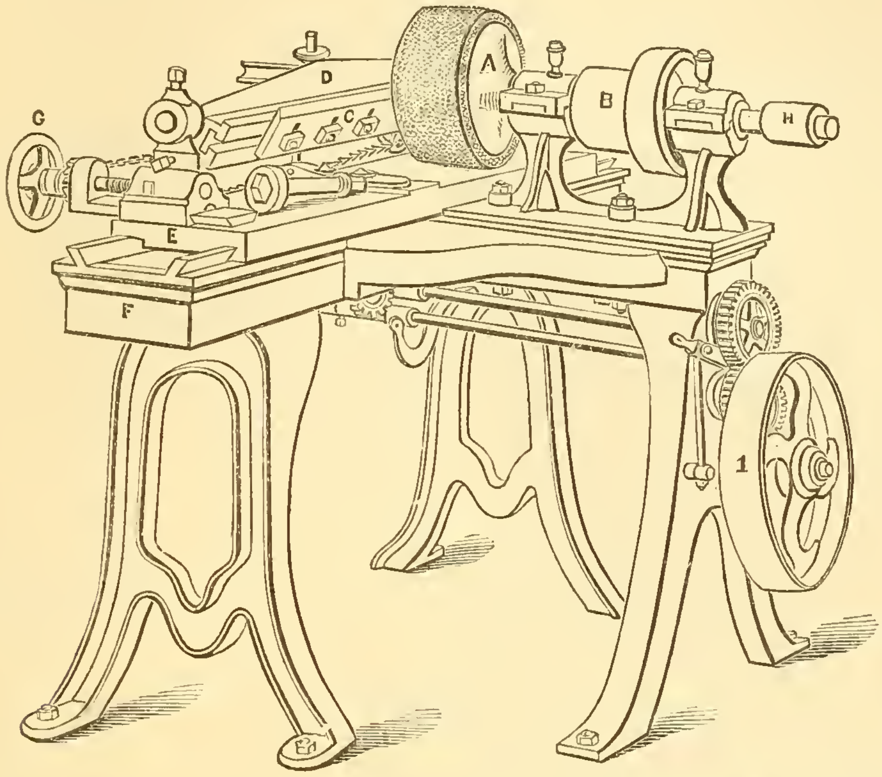
1328.




generally used for promiscuous work in machine shops. The rest *B* is made angular to facilitate the grinding operations performed on the side as well as on the circumferential face. In using this class of machine, it is highly essential to distribute the work evenly over all parts of the wheel face, thus preventing it from wearing in ridges. In Fig. 1329 is shown a machine designed by the Tanite Company for grinding wood-planing-machine knives or cutters. The knife is clamped at the requisite angle against the rest, and is presented to the side face of the emery-wheel. The rest is traversed by a chain fed by hand, and by a self-acting feed by belt and pinion-gear at the back of the machine. *A* is the emery-wheel secured to the arbor, driven by the step-pulley *B*. *C* is a planer-knife,

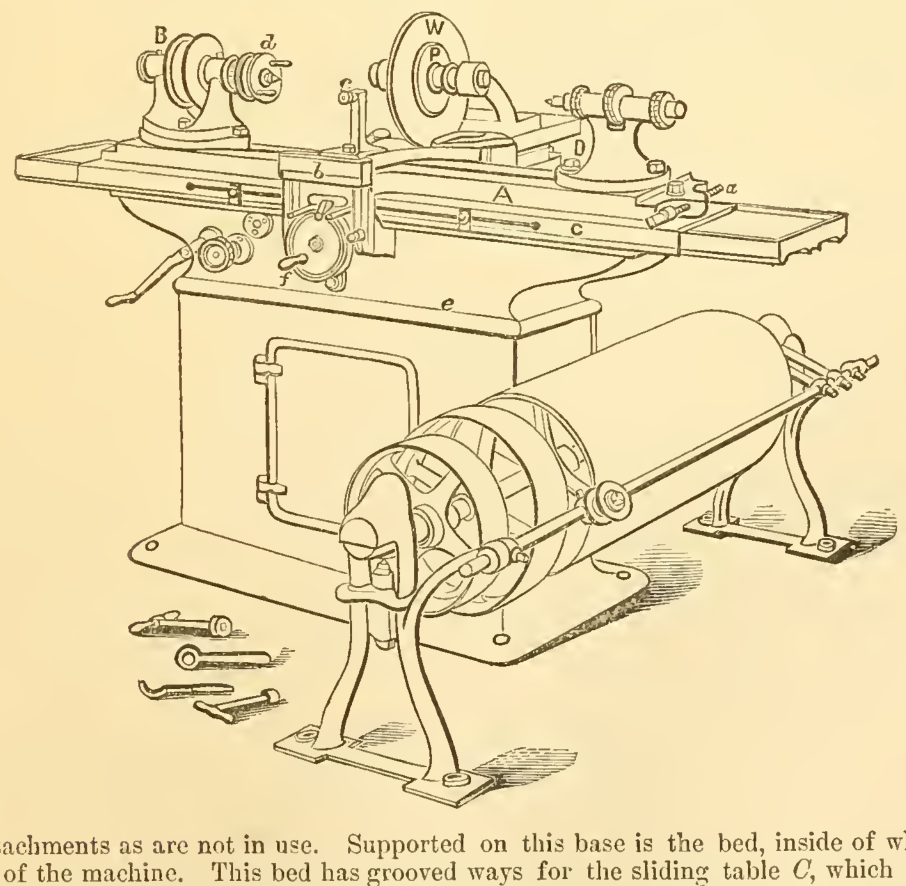
secured to the traversing rest *D*. *E* is the carriage supporting the rest *D*. *F* is the bed upon which the carriage *E* slides. *G* is the hand-wheel by which the hand-chain feed is operated. *H* is a driving-pulley, to be connected by belt to the feed-pulley *I*, which operates the feed-gears shown.

1329.




For grinding circular work, such as spindles, arbors, or bearings, the class of grinding machine shown in Fig. 1329 is employed. The particular machine illustrated, and the two shown in Figs. 1330 and 1331, are the design of Messrs. Brown & Sharp of Providence, R. I. In Fig. 1330, the base forms a support for the machine, and also provides a convenient closet for holding wheels and such

1330.

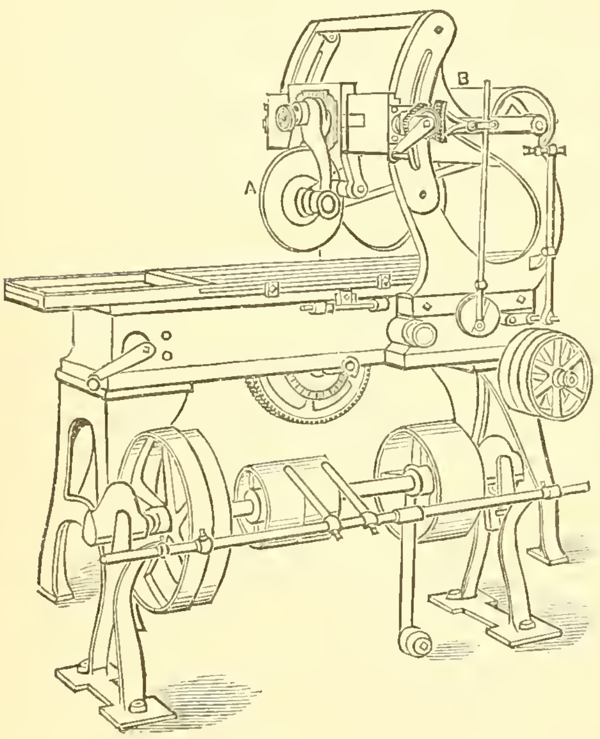



parts or attachments as are not in use. Supported on this base is the bed, inside of which are the feed-works of the machine. This bed has grooved ways for the sliding table *C*, which table moves automatically, similar to the table of a planing machine, and is of sufficient length and of a suitable form fully to protect the slides and feed-works from grit and dust. Placed upon the table *C* is the

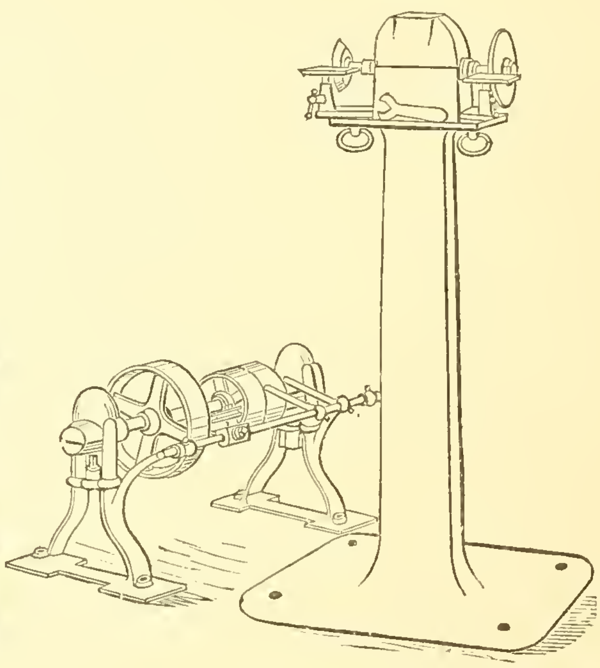
additional table *A*, fastened in the middle, so as to allow a lateral movement of the ends, which is regulated by the tangent screw *a* and gauged by a graduated arc. Upon the table *A* are fastened the head and foot stocks of the machine, the centres of which, it will be noticed, are, by the lateral movement of the table, always kept in line, either for straight or taper grinding. The head-stock *B* also moves upon a perpendicular central bearing, allowing the spindle to be placed at any given angle to the slides of the machine, affording a ready means for grinding taper holes. The base of this head is graduated to degrees. One of Horton's 6-inch universal chucks is fitted to the spindle at *d* for holding circular work in grinding out holes, etc. The cast-iron pan *b* receives the grit and water from the grinding wheel, and also supports the back rest. The wheel-arbor and stand are adjustable upon the table *D*, which is fastened upon a bed which moves around a fixed centre, enabling the table *D* to be placed and operated at any required angle to the larger table *C*, by which movement angular cutters and work of a similar character can be ground. The table *D*, at whatever angle placed, is operated by the handle *f*. This handle, with accompanying disk, is provided with a clamp-gauge which regulates the relation of the grinding wheel to the work upon the centres of the machine. Graduations made upon the bed supporting the table *D* determine any desired angle. The operation is as follows: The work is placed between the centres and revolved in the usual manner at a high speed. The emery-wheel *W* is revolved in an opposite direction by means of the pulley *P*, which is connected by belt to the countershaft shown in the figure at the foot of the machine.

The design of the machine shown in Fig. 1331 is as nearly that of an ordinary iron-planer as the requirements of the case will admit. The emery-wheel *A*, which takes the place of the steel tool, is

1331.




1332.



driven by belt from the drum *B*, the latter extending across the machine, so that the belt may travel along it as the sliding head carrying the emery-wheel is fed. To maintain the tension of the emery-wheel belt, notwithstanding the raising or lowering of the emery-wheel to suit different thicknesses or heights of work, the cross-slide, as will be seen, slides in slots in the side frames or standards, the slots being the section of a circle struck from the centre of the driving drum.

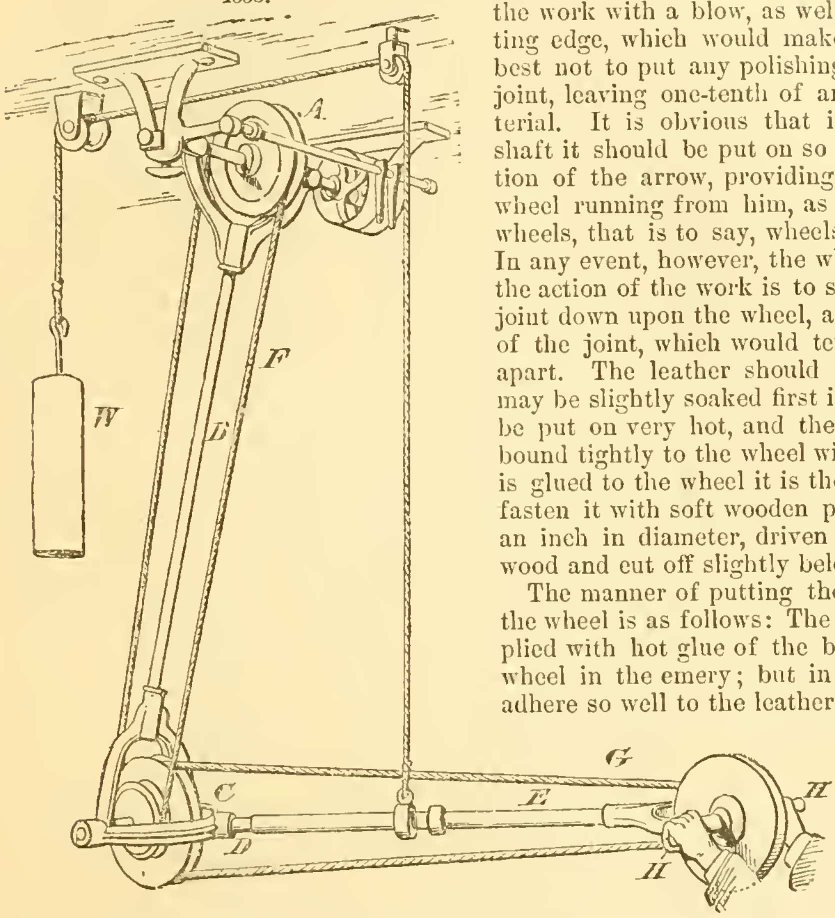
In Fig. 1332 is shown an emery-grinder for sharpening small tools by hand.

In addition to the foregoing fixed machines, there is the swing-frame machine shown in Fig. 1333, in which *A* is the overhead driving-pulley; *B* is a frame pivoted at the top upon the shaft to which *A* is attached, and carrying at the lower end the grooved step-pulleys or cone *C* and the frame *D*; *E* is a telescopic rod carrying the emery-wheel at its outer end, the object being to permit the emery-wheel to revolve with the plane of its motion at any angle. The frame *B* swings from its top as a centre; the frame *D E* swings vertically, using its bearings upon the end of the frame *B* as a pivot. The twist of the emery-wheel permitted by the telescopic arm enables it, while being driven by the belts *F G*, to be traversed or operated upon any surface; while the counterweight *W* operates to relieve the overhanging weight of the frames and emery-wheel. The operator guides the emery-wheel to its work by holding the handles *H H*.

*Emery Polishing Wheels* are built up in sections of wood fastened together by gluing, and with wooden pegs in place of nails or screws. The joints of the sections or segments are broken; that is to say, suppose in Fig. 1334 that 1, 2, 3, etc., up to 8, represent the joints of the 8 sections of wood forming one layer of the wheel, the next 8 sections would have their joints come at the dotted lines *A*, *B*, *C*, etc., up to *H*. The thickness of these sections is usually made of well-seasoned soft wood, such as pine; and to prevent them from warping after being made into a wheel, it is advisable to cut out the sections somewhere near the size in the rough and allow them to lie a day or two before planing them up and fitting them together, the object being to allow any warping that may take place

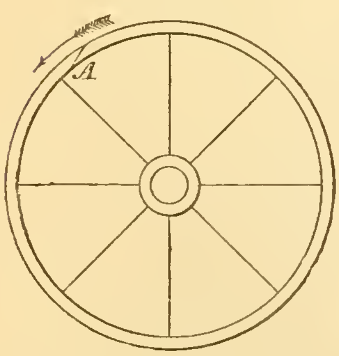
to do so before the pieces are worked up into the wheel, because if the warping takes place afterward it will be apt to throw the wheel out of true. To cover the circumference of the wheel sole leather is used, its thickness being about a quarter of an inch; it should be put on soft and not hardened by hammering at all, and with the flesh side to the wood. The joint of the leather should not be made straight, but diagonal with the wheel face, the leather at the edge of the joint being chamfered off as shown in Fig. 1335 at *A*, and the joint made diagonal. If the leather was put on with a square butt joint, there would be apt to be a crease in the joint, and the emery or other polishing material would then strike the work with a blow, as well as presenting a keener cutting edge, which would make marks in the work. It is best not to put any polishing material on the immediate joint, leaving one-tenth of an inch clear of polishing material. It is obvious that in fastening the wheel to its shaft it should be put on so that it will run in the direction of the arrow, providing the operator works with the wheel running from him, as is usually the case with large wheels, that is to say, wheels over 18 inches in diameter. In any event, however, the wheel should be put on so that the action of the work is to smooth the edge of the leather joint down upon the wheel, and not catch against the edge of the joint, which would tend to rough it up and tear it apart. The leather should be glued to the wheel, which may be slightly soaked first in hot water. The glue should be put on very hot, and the leather applied quickly and bound tightly to the wheel with a band. After the leather is glued to the wheel it is the custom in Europe to further fasten it with soft wooden pegs, about three-sixteenths of an inch in diameter, driven through the leather into the wood and cut off slightly below the surface of the leather.

1333.

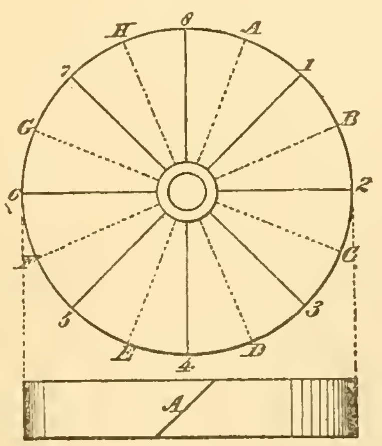



The manner of putting the emery and fastening it upon the wheel is as follows: The face of the wheel is well supplied with hot glue of the best quality, and some roll the wheel in the emery; but in this case the emery does not adhere so well to the leather as it does when the operation is performed as follows: Let the wheel either remain in its place upon the shaft, or else rest it upon a round mandrel, so that the wheel can revolve upon the same. Then apply the hot glue to about a foot of the circumference of the wheel, and cover it as quickly as possible with the emery. Then take a piece of board about three-fourths of an inch thick and 28 inches long, the width being somewhat greater than that of the polishing wheel, and, placing the flat face of the board upon the circumferential surface of the wheel, work it by hand, and under as much pressure as possible, back and forth, so that each end will alternately approach the circumference of the wheel, as illustrated in Fig. 1336, the movement being indicated by the dotted lines. By adopting this method the whole pressure placed upon the board is brought to bear upon a small area of the emery and leather, and the two hold much more firmly together. The emery thus glued will be thicker at the junction of the gluing operations; but it is

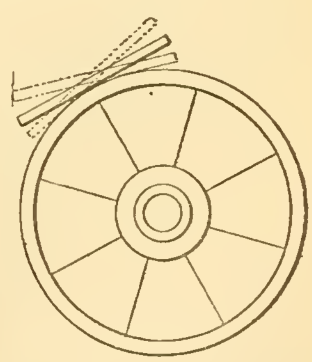
1334.




1335.




1336.



the practice where this plan is employed to true up the new wheel by a round iron bar, resting upon a wooden-frame rest kept for the purpose. The speed at which these wheels are used is about 7,000 feet per minute. The finest of emery applied upon wheels of this kind is used for cast-iron, wrought-iron, and steel, to give to the work a good ordinary machine finish. But if a high polish or glaze is

required, the wheels are coated with flour emery; and a wheel is made into a glaze-wheel by wearing the emery down until it gets glazed, applying occasionally a little grease to the surface of the wheel. J. R.

ENERGY, POTENTIAL AND KINETIC. See DYNAMICS.

ENGINE, BEATING. See PAPER-MAKING.

ENGINE, ELECTRO-MAGNETIC. See ELECTROMOTORS.

ENGINE, WASHING. See PAPER-MAKING.

ENGINES, AËRO-STEAM AND BINARY VAPOR. If the products of combustion, after leaving the furnace of a steam-boiler, are forced into the boiler, mingling with the water and steam, instead of escaping into the atmosphere, it is reasonable to infer that a greater effect can be realized from the fuel. There have been numerous engines invented to apply this principle, and some of them have given very satisfactory results for a short time. So far, however, there have been many mechanical difficulties that have interfered with their continued success, so that it is scarcely necessary to present detailed descriptions showing their construction. The reader will find numerous articles on the subject in the files of technical journals, and is especially referred to a paper on "The Theory of Aëro-Steam Engines," by J. A. Henderson, published in the *Journal of the Franklin Institute* for July, August, and September, 1874, and to an article on "The Warsop Aëro-Steam Engine," by R. Eaton, in "Proceedings of the Institution of Mechanical Engineers," 1870.

Another plan of increasing the efficiency of steam-engines, that has been very popular with inventors, is to add a second engine, which is driven by the vapor of a liquid having a low boiling-point, and receiving its heat from the exhaust steam from the first engine. Bisulphide of carbon is the liquid ordinarily employed; and the use of the second engine generally increases the economy as a matter of course, since the effect is to increase the range of temperature through which the engine works.

Although many binary-vapor engines have been brought to the notice of the public, they have been usually short-lived, and scarcely warrant an extended notice. There are many practical objections to most forms of binary-vapor engines, and they seem to possess no advantage, theoretical or practical, that cannot be obtained by the use of a single fluid, with less complication and expense. R. H. B.

ENGINES, AIR. The action of air-engines, like that of all other heat-engines, consists in admitting the air at a high temperature and pressure, and allowing it to perform work on the piston and thus reduce its pressure and temperature, when it is either exhausted into the atmosphere and a fresh supply is introduced, or it is again heated and compressed for a repetition of the former process. It will be seen from the above that air has some advantages over steam as a working fluid under certain circumstances. The efficiency of an engine depends upon the limits of temperature to which the working fluid is subjected, and it is practicable to use a higher working temperature with air than with steam, because there is no fixed relation between the temperature and pressure of air, such as exists in the case of steam.

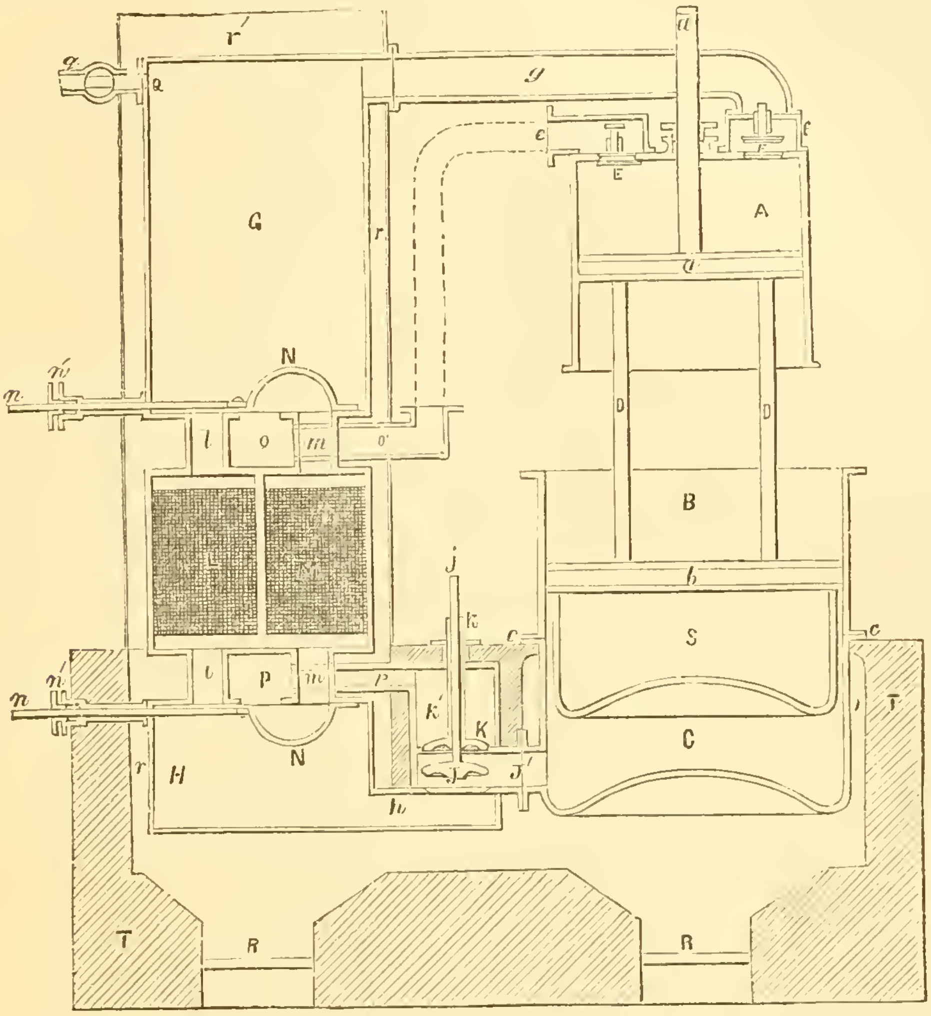
The principal varieties of air-engines may be classified by the following distinctive features: 1. Change of temperature at constant pressure. 2. Heat received and rejected at a pair of constant pressures. 3. Change of temperature at constant volume.

Ericsson's engine, best known as the caloric engine, may be taken as an example of the first class. In this engine, air is admitted from the atmosphere to the compressing pump at the lowest working temperature, and compressed, the temperature being maintained constant by the action of some refrigerating apparatus. The air when compressed enters a receiver. It is then admitted to the working cylinder, being heated in its passage to the higher temperature, so that its volume is increased and the pressure remains constant under the movement of the piston, then expands with its temperature maintained constant at the higher limit, and is finally expelled into the atmosphere, giving up its heat to the regenerator, to be used in heating the volume of air next introduced.

This engine is represented in Figs. 1337 and 1338. In Fig. 1337, *A* and *B* are two cylinders of unequal diameter, accurately bored and provided with pistons *a* and *b*, the latter having air-tight metallic packing rings inserted at their circumferences. *A* is the supply cylinder, and *B* the working cylinder; *a'*, piston-rod attached to the piston *a* working through a stuffing-box in the cover of the supply cylinder. *C* is a cylinder with a spherical bottom attached to the working cylinder at *c c*; this vessel is called the expansion heater. *D D*, rods or braces connecting together the supply piston *a* and the working piston *b*. *E* is a self-acting valve opening inward to the supply cylinder; *F*, a similar valve, opening outward from said cylinder, and contained within the valve-box *f*. *G* is a cylindrical vessel, which is called the receiver, connected to the valve-box *f* by means of the pipe *g*. *H*, a cylindrical vessel with an inverted spherical bottom, is called the heater. *J*, a conical valve supported by the valve-stem *j*, and working in the valve-chamber *J'*, which chamber also forms a communication between the expansion heater *C* and heater *H*, by means of the passage *h*. *K* is another conical valve, supported by the hollow valve-stem *k*, and contained within the valve-chamber *k'*. *L* and *M*, two vessels of cubical form filled to their utmost capacity, excepting small spaces at top and bottom, with disks of wire net, or straight wires closely packed, or with other small metallic substances, or mineral substances, such as asbestos, so arranged as to have minute channels running up and down. These vessels *L* and *M*, with their contents, are termed regenerators. *l l*, *m m*, pipes forming a direct communication between the receiver *G* and the heater *H*, through the regenerators. *N N*, two ordinary slide-valves, arranged to form alternate communications between the pipes *l l* and *m m*, and the exhaust-chambers *O* and *P*, on the principle of the valves of ordinary high-pressure steam-engines; *n n*, valve-stems working through stuffing-boxes *n' n'*; *p*, pipe communicating between the valve-chamber *k'* and exhaust-chamber *P*; *o'*, pipe leading from exhaust-chamber *O*; *Q*, pipe leading into the receiver *G*, provided with a stop-cock *q*. *R R*, fireplaces for heating the vessels *H* and *C*; *r r r r*, flues leading from said fireplaces, and terminating at *r'*. *S*, a cylindrical vessel attached to the working piston *b*, having a spherical bottom corresponding to the expansion vessel *C*.

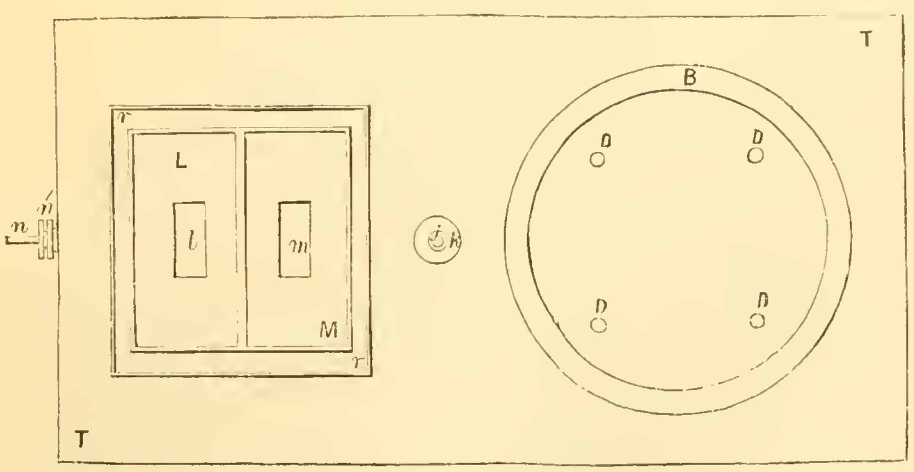
This vessel *S*, which is the heat-intercepting vessel, is to be filled with fire-clay at the bottom, and ashes, charcoal, or other non-conducting substances toward the top, its object being to prevent any intense or injurious heat from reaching the working piston and cylinder. *T' T*, brickwork or other fire-proof material surrounding the fireplaces and heaters. Fig. 1338 represents a sectional plan of Fig. 1337.

1337.



The piston-rod *a'* only receives and transmits the differential force of the piston *b*, viz., the excess of its acting force over the reacting force of piston *a*. This differential force imparted to said piston-rod may be communicated to machinery by any of the ordinary means, such as links, connecting-rods, and cranks, or it may be transmitted directly for such purposes as pumping or blowing. The conical valves *K* and *J* may be worked by any of the ordinary means, such as eccentrics or cams,

1338.



provided the means adopted be so arranged that the valve *K* will begin to open the instant that the piston *b* arrives at the full up stroke, and be again closed the instant the piston arrives at full down stroke, while the valve *J* is made to open at the same moment, and to close shortly before or at the termination of the up stroke. In like manner, the slide-valve *N* is to open and close as the piston *b* arrives respectively at its up and down stroke, similar to the slide-valve of an ordinary high-pressure engine.

Before starting the engine, fuel is put into the fireplaces $R\ R$, and ignited, a slow combustion being kept up until the heaters and lower parts of the regenerators shall have been brought to a temperature of about 500°. By means of a hand-pump, or other simple means, atmospheric air is then forced into the receiver $G$ through the pipe $Q$, until there is an internal pressure of some 8 or 10 lbs. to the square inch. The valve $J$ is then opened, as shown in the figure; the pressure entering under the piston $b$ will cause the same to move upward, and the air contained in $A$ will be forced through the valve $F$ into the receiver. The slide-valves $N\ N$ being, by means of the two stems $n\ n$, previously so placed that the passages $l\ l$ are open, the air from the receiver will pass through the wires in $L$ into the heater $H$, and further into $C$, the temperature of the air augmenting and its volume increasing as it passes through the heated wires and heaters. The smaller volume forced from $A$ will, in consequence thereof, suffice to fill the larger spaces in $C$. Before the piston arrives at the top stroke, the valve $J$ will be closed, and at the termination of the stroke the valve $K$ will be opened; the pressure from below being thus removed, the piston will descend and the heated air in $C$ will pass through $k'$, $p$, $P$, and $m$ into the regenerator $M$, and, in its passage through the numerous small spaces or cells formed between the wires, part with the heat, gradually falling in temperature until it passes off at $o'$, nearly deprived of all its heat. The commencement of the descent of the piston $a$ will cause the valve $F$ to close and the valve $E$ to open, by which a fresh charge of atmospheric air is taken into the cylinder $A$. At the termination of the full down stroke, the valve $K$ is closed and the valve $J$ again opened, and thus a continued reciprocating motion kept up. It will be evident that after a certain number of strokes the temperature of the wires or other matter contained in the regenerators will change; that of $M$ will become gradually increased, and that of $L$ diminished. The position of the side valves $N\ N$ should, therefore, be reversed at the termination of every fifty strokes of the engine, more or less, which may be effected either by hand or by a suitable connection to the engine. The position being, by either of these means, accordingly reversed to that represented in the drawing, the heated air or other medium passing off from $C$ will now pass through the partially cooled wires in $L$, while the cold medium from the receiver will pass through the heated wires of $M$, and on entering $H$ will have attained nearly the desired working temperature. In this manner the regenerators will alternately take up and give out heat, whereby the circulating medium will principally become heated, independently of any combustion, after the engine shall have been once put in motion.

The relative diameter of the supply and working cylinders will depend on the expansibility of the acting medium employed; thus, in using atmospheric air or other permanent gases, the difference of the area of the pistons may be nearly as 2 to 1, while in using fluids, such as oils, which dilate but slightly, the difference of area should not much exceed one-tenth. In employing any other medium than atmospheric air, it becomes indispensable to connect the outlet pipe $o'$ and the valve-box $e$ of the outlet valve $E$, as indicated by dotted lines in the drawing, these dotted lines representing the requisite connecting-pipe. The escaping air or fluid at $o'$ will, when such a connecting-pipe has been applied, furnish the supply cylinder independently of other external communication, and the acting medium will perform a continuous circuit through the machine under this arrangement; the operation being in other respects as before described. The working cylinder may be placed horizontally or otherwise, and it may be made double-acting; a heat-intercepting vessel may be applied at each end of the working piston, as also an expansion heater at each end of the working cylinder. Four working cylinders similar to the above were placed in the steamer Ericsson.

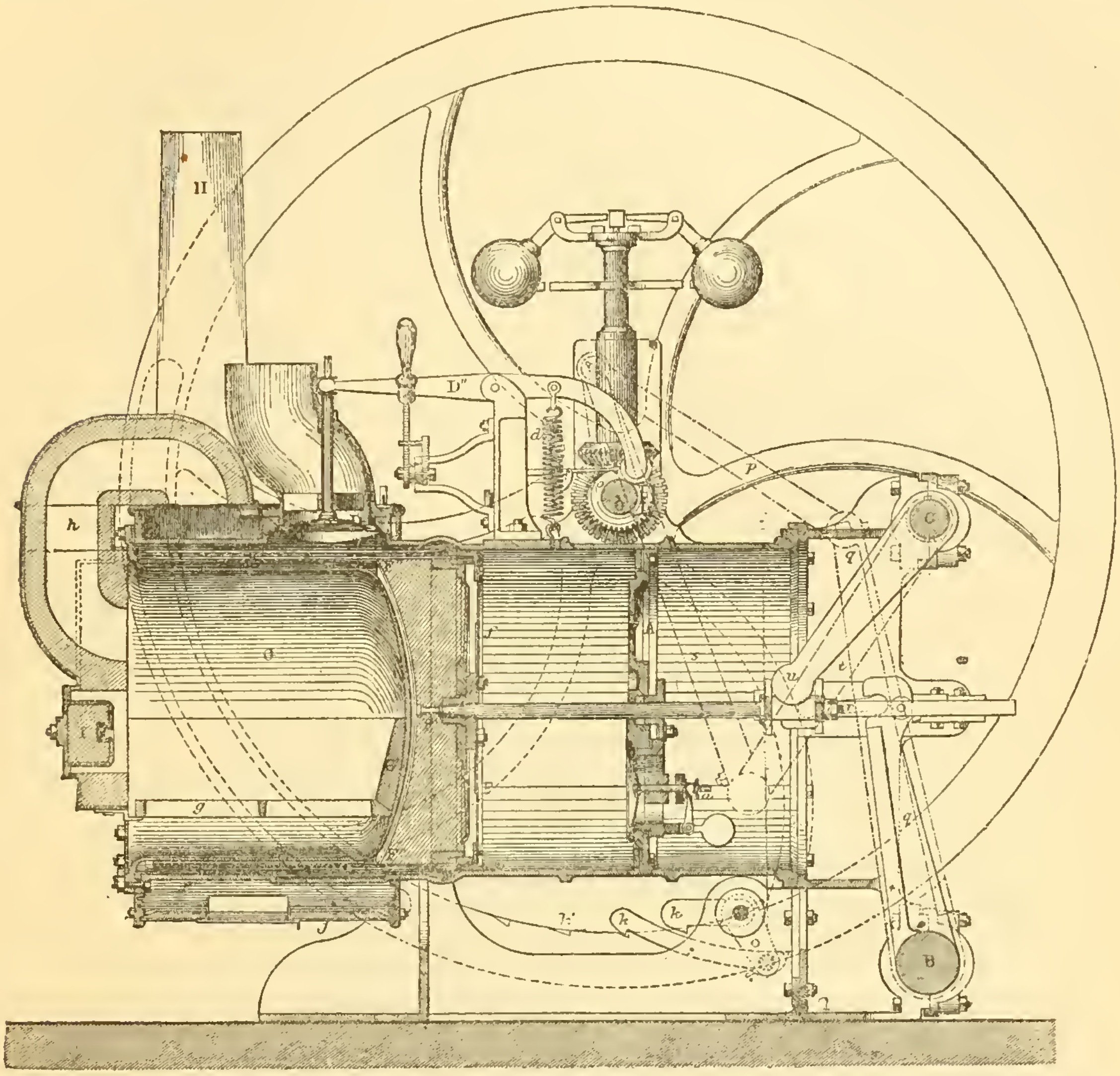
A modification of the engine just described, which has been used to a considerable extent for light work, is represented in Fig. 1339. There are two pistons working in one cylinder, $A$ being the driving piston and $F$ the pump-piston. $G$ is the furnace, $B$ is the fly-wheel shaft, and the driving piston is connected to it by the crank $o$, connecting-rod $p$, lever $q$, and rod $r$. The crank $o$ also gives motion to the pump-piston $F$, through the connecting-rod $s$, and the cranks $t\ w$, which are secured to the shaft $C$, making an angle of 7° with each other. The piston $A$ has a valve opening inward, as also has the supply piston $F$. This latter piston is lined with a non-conducting material on the side next the furnace, and it carries on its periphery a cylindrical bell, which works in the narrow annular space between the walls of the furnace and the surrounding chamber. The valve in $F$ opens above this bell, so that the air passing through this valve traverses the annular space and thus has its temperature raised. $D$ is the exhaust-valve, kept to its seat by a spring, when not acted upon by the cam $D'$. On account of the peculiar connections of the two pistons, they have a differential movement, so that the operation of the engine is as follows:

When the two pistons are moving inward, $F$ at first goes faster than $A$, and air is drawn into the space between the two pistons from the atmosphere. $A$ then gains upon $F$, and the air between the two pistons is compressed. $F$ completes its stroke before $A$, and commences the return stroke while $A$ is still moving inward, so that the air between the pistons passes through the valve in $F$, and becomes heated in the annular space around the furnace. While $A$ is making the return stroke, $F$ continues to move faster, and constantly displaces the air between the two pistons. A little before the end of the outward stroke, the two pistons are nearly in contact, but the distance between them increases slightly at the end of the stroke. The exhaust-valve is then opened and the heated air escapes, the valve being kept open during the inward stroke, until the compression between the two pistons commences. As the working pressure is exerted in this engine for less than half a revolution, a heavy fly-wheel is required to maintain the motion; and the fly-wheel is counterweighted so that the weight is descending during what may be called the negative part of the revolution. To start the engine, the fly-wheel must be turned until the two pistons occupy the proper position, and there is a click attachment working in notches in the fly-wheel, to facilitate the turning by hand. In a test of one of these engines made by M. Tresca (*Annales des Mines*, 5th Series, xix.), the consumption of coal was about 9 lbs. per horse-power per hour.

In Shaw's engine, Figs. 1340 and 1341, the products of combustion pass from the furnace into

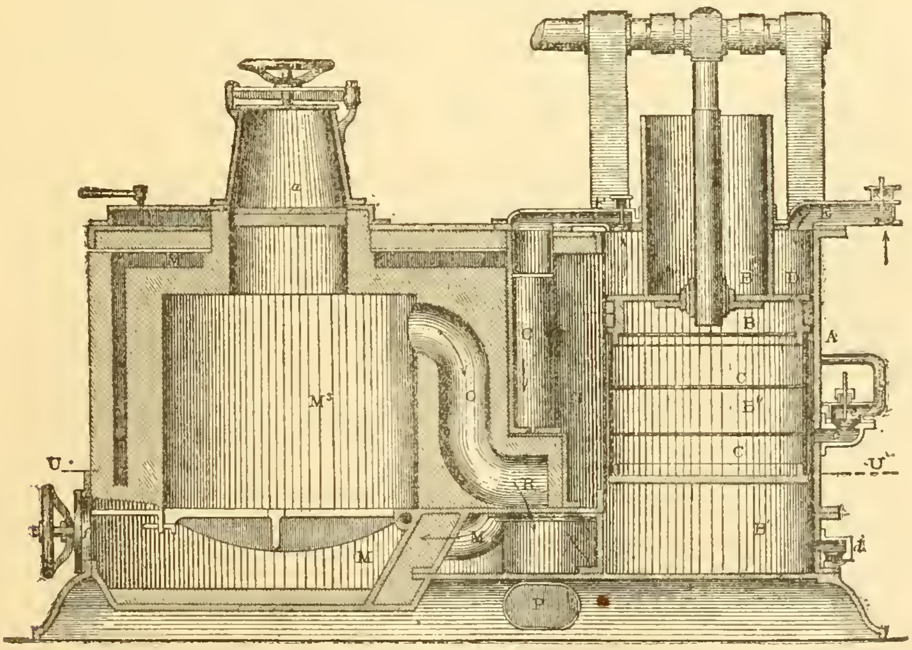
the cylinder, and at the completion of the stroke of the working piston are exhausted, passing through a regenerator and thus being deprived of some heat, which is imparted to the next charge

1339.



of air drawn in. There is a double wall around the furnace, and all the air drawn in passes through the space between the two walls, having its temperature still more increased before entering

1340.



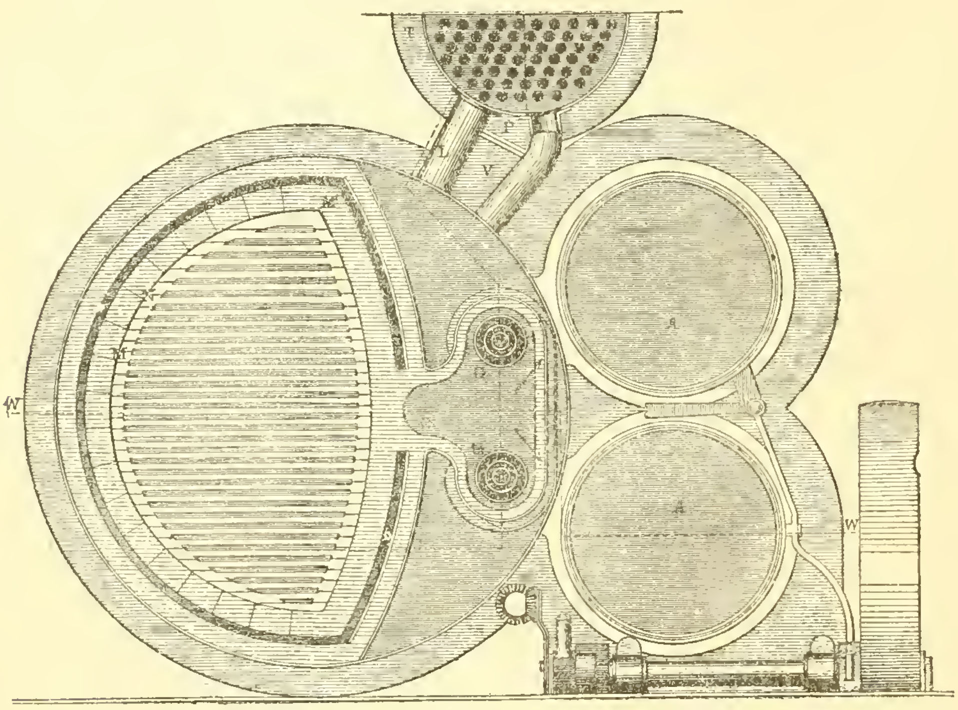
the furnace. The efficient means employed for heating the air constitute the chief merit of this engine. As shown in Figs. 1340 and 1341, there are two working cylinders *A A*, each single-acting,

and the compressing pumps are formed by trunks on the upper sides of the pistons. $B$ is one of the pistons, and $B'$ the corresponding trunk. $T$ is the regenerator. Air is drawn in by the compressing pump through the valve $E$, and forced into the regenerator and furnace through the valve $F$. $P$ is the exhaust-pipe.

The engines that have just been described are necessarily limited to comparatively low pressures, and hence must be very bulky when designed to develop considerable power. This limitation is an essential condition of their design, because the original pressure of the air which is compressed and heated is that of the atmosphere. If, however, the working air be confined in the machine, and originally compressed to a high pressure, this difficulty disappears. Thus, suppose it is found practicable to maintain a temperature in a given air-engine sufficient to double the original pressure of the air. Then, if the air were admitted at the pressure of the atmosphere, the available pressure, after heating, would be about 15 lbs. per square inch. But if the supply of air were drawn from a reservoir, in which the pressure was 60 lbs. per square inch, the effect of increasing the temperature to the same point as in the former case would be to double the original pressure, making it 120 lbs. per square inch. It seems strange that the majority of inventors should have ignored this significant principle, and that too in the face of the example afforded by one of the first air-engines ever constructed, and which seems, from all accounts, to have been more successful and economical than any of its successors. Reference is made to Stirling's engine, invented by Robert Stirling of Scotland in 1827, and put in operation at the Dundee Foundry in 1840. The construction of this engine is clearly illustrated in Figs. 1342 to 1344, and the accompanying description.

Two strong air-tight vessels are connected with the opposite ends of a cylinder, in which a piston works in the usual manner. About four-fifths of the interior space in these vessels is occupied by

1341.

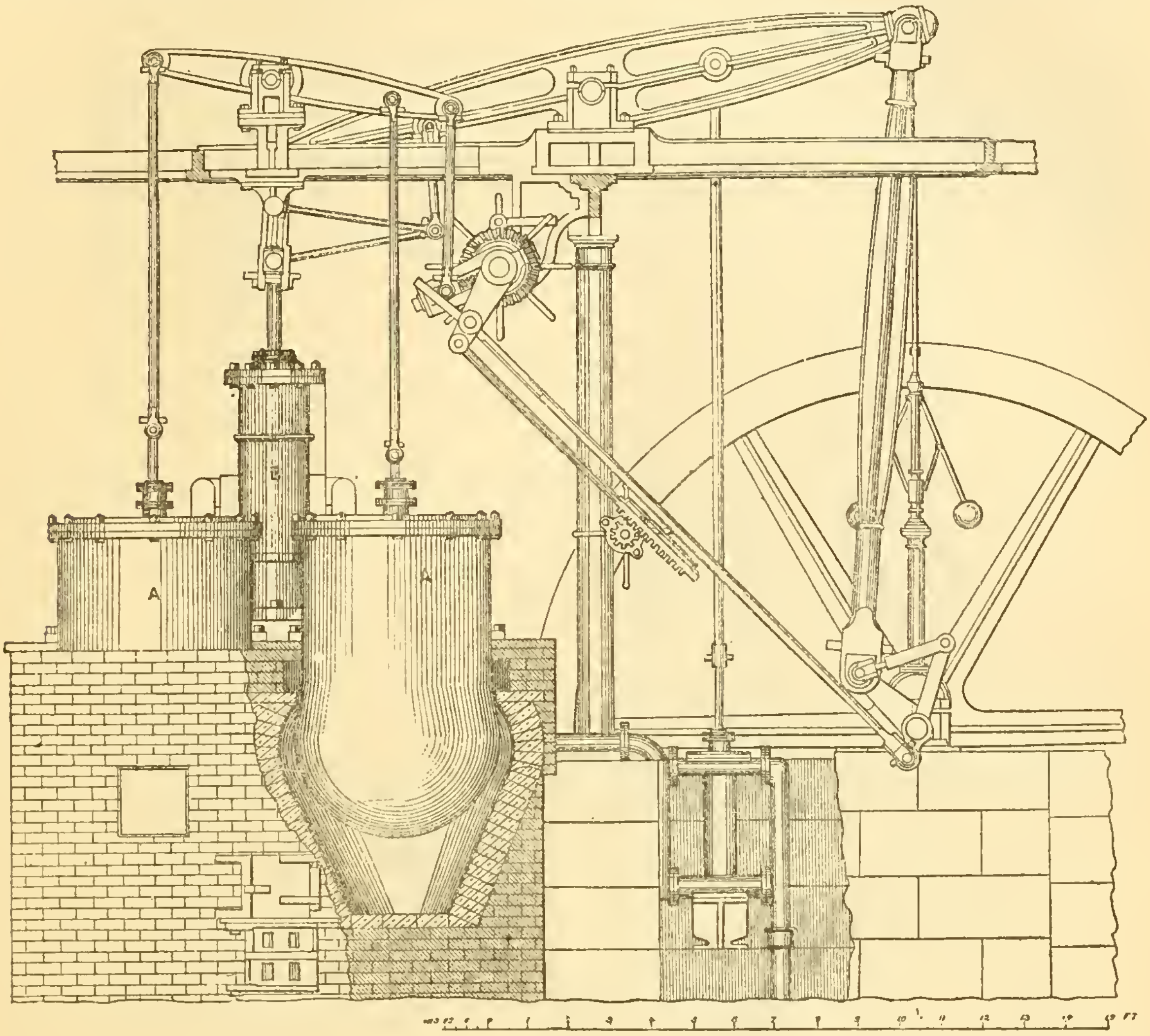


two similar air-tight vessels or plungers, which are suspended to the opposite extremities of a beam, and capable of being alternately moved up and down to the extent of the remaining fifth. By the motion of these interior vessels, which are filled with non-conducting substances, the air to be operated upon is moved from one end of the exterior vessels to the other; and as one end is kept at a high temperature, and the other as cold as possible, when the air is brought to the hot end it becomes heated and has its pressure increased, and when it is brought to the cold end its heat and pressure are diminished. Now, as the interior vessels necessarily move in opposite directions, it follows that the pressure of the inclosed air in the one vessel is increased, while that of the other is diminished. A difference of pressure is thus produced upon the opposite sides of the piston, which is thereby made to move from one end of the cylinder to the other; and by continually reversing the motion of the suspended bodies or plungers, the greater pressure is successively thrown upon a different side, and a reciprocating motion of the piston is kept up. The piston is connected with a fly-wheel in any of the usual modes, and the plungers, by whose motion the air is heated and cooled, are moved in the same manner, and nearly at the same relative time, with the valves of a steam-engine. The power is greatly increased and made more economical by using somewhat highly-compressed air, which is at first introduced, and is afterward maintained, by the continual action of an air-pump. The pump is employed in filling a separate magazine with compressed air, from which the engine can be at once charged to the working pressure.

If all the heat, however, which is necessary to raise the air to the required temperature, were to be thrown away or lost every time that the air is cooled, the power produced by its expansion and contraction would be much more expensive than that which is gained by the use of steam. In order, therefore, to understand how the work of a good steam-engine has been done with about one-third of the fuel consumed by it, it is necessary to point out the method by which the greater part of the

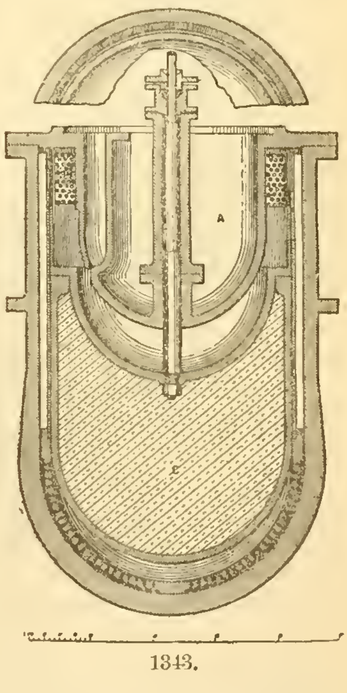
heat is preserved, and is used repeatedly, in expanding the air, before it is finally wasted or lost. For this purpose, when it is necessary to cool the air, after it has been brought to its greatest heat,

1342.




it is not at once brought into contact with the coldest part of the vessels. This would indeed effectually cool it, but the heat when thus extracted would be entirely lost, because it could never again be taken up by a body warmer than itself. Instead of this, therefore, the air is made to pass from the hot to the cold end of the air-vessel through a multitude of narrow passages, whose temperature is at first nearly as great as that of the hot air, but gradually declines till it becomes nearly as low as the coldest part of the air-vessel. Now, as every body by contact will give out heat to one that is colder than itself, the air, when it enters the narrow passages, must give out a portion of its heat even to the hottest part of these passages, and must continue in its progress to give out more and more as the temperature of the passages is diminished, till at last, when it is ready to escape into the cold part of the vessel, there is only a small portion of the heat to be extracted, in order to bring it to the lowest temperature required. By far the greater part of the heat, therefore, has been left behind in the metal which forms the passages, and which is so contrived and arranged as to retain that heat until it is again required for heating the air. It must be evident also, from the manner in which the heat has been distributed, or spread out, over the whole length of those passages, that it is capable of being again employed in heating and expanding the air; for when the cold air is again made to enter the passages for the purpose of being heated, it immediately comes into contact with matter that is hotter than itself, and consequently begins to acquire heat even at its first entrance; and as it is successively applied to surfaces of a greater temperature, it continues to receive more and more heat, so that when it comes at last to the hot end of the vessel, it requires but a small addition to its temperature to give it the elasticity which is necessary to move the piston. Thus, instead of being obliged to supply, at every stroke of the engine, as much heat as would be sufficient to raise the air from its lowest to its highest temperature, it is necessary to furnish only as much as will heat it the same number of degrees by

1344.

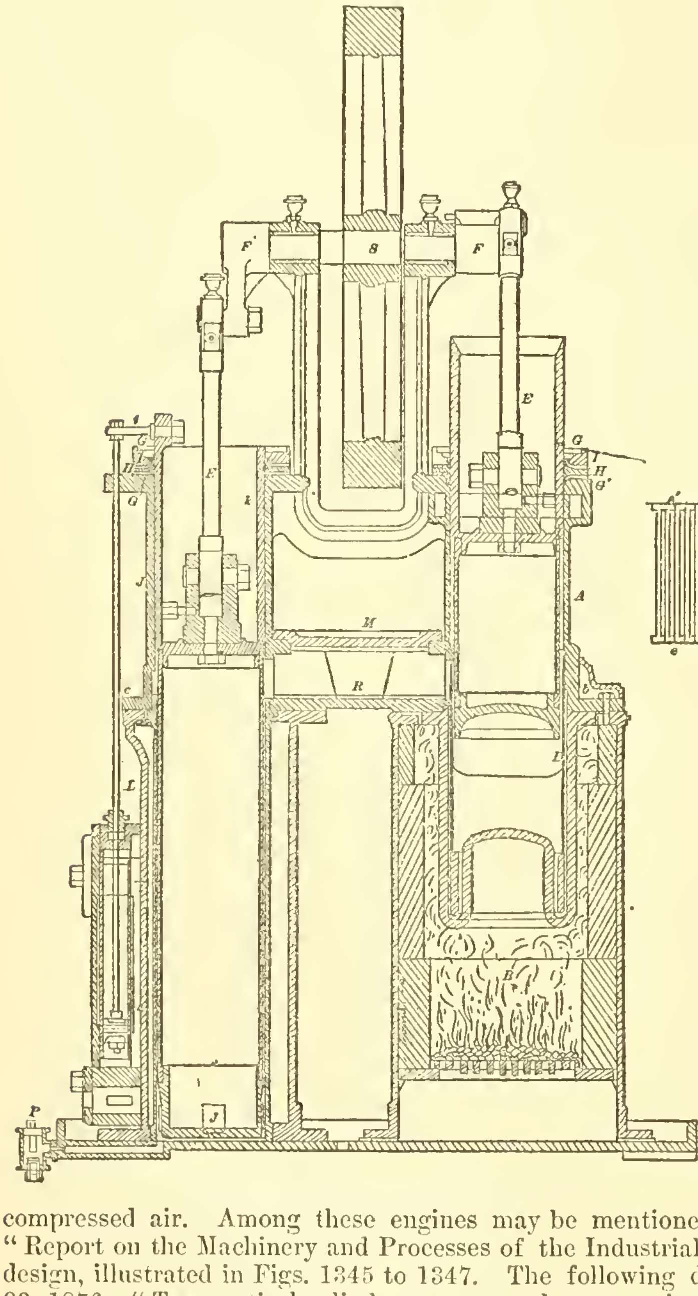



1343.

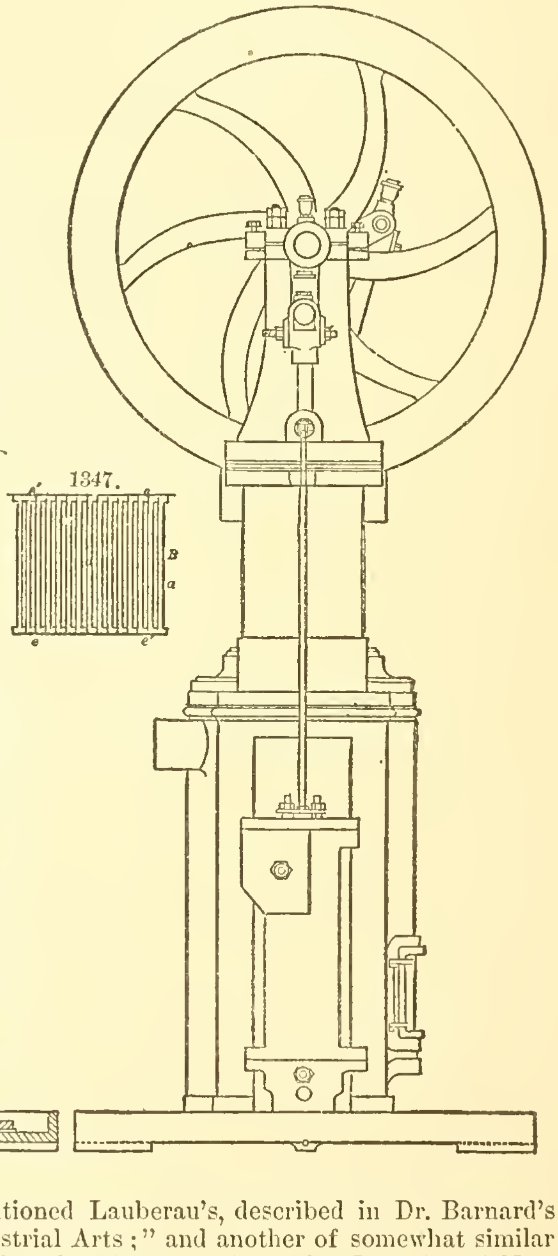
which the hottest part of the air-vessel exceeds the hottest part of the intermediate passages. In an account of the performance of this engine, given by Mr. Patrick Stirling (see "Transactions of the Institution of Engineers in Scotland," vol. iv.), it is stated that the dimensions of the working cylinder, which was double-acting, were 16 × 48 inches; the minimum pressure 10 atmospheres, maximum pressure $15\frac{1}{2}$ atmospheres; probable range of temperature, 100° to 600° F.; average horse-power, measured on friction-brake, 37; and coal consumed per day, 1,000 lbs., corresponding to a consumption of 2.7 lbs. of coal per net horse-power per hour, the consumption frequently falling as low as 2.5 lbs. per horse-power. The engine was used for four years in the regular work of the foundry, and was finally abandoned on account of the heaters burning out. From the above record, it seems reasonable to believe that inventors would do well to turn back to Mr. Stirling's work, and take up the matter where he left off.

There have been several engines constructed on the general principle of Stirling's, so far as using the working air continuously, but they have generally neglected the second feature, of using highly

1345.



1346.



1347.

compressed air. Among these engines may be mentioned Lauberau's, described in Dr. Barnard's "Report on the Machinery and Processes of the Industrial Arts;" and another of somewhat similar design, illustrated in Figs. 1345 to 1347. The following description is from the *Iron Age* of Nov. 23, 1876: "Two vertical cylinders, power and compression, are mounted side by side upon a flanged bed-plate, and form the lower part of the housing for the crank-shaft bearings, which are of sufficient height to give the necessary length of connecting-rods. The power cylinder is fitted to a cylindric heater *C* with a recessed bottom, beneath which is a small furnace. By a peculiar arrangement of the interior of the cylinder *A* and the lower part of the piston (or more properly the plunger), the compressed air is made to pass in a thin sheet over the surface of the heater, and becomes heated to the required temperature almost instantly. The compression cylinder, by means of a similar device for spreading the expanded air after its discharge from the power cylinder, cools it to or below the temperature of the atmosphere by the circulation of water through a jacket by which it is surrounded. Connecting the two cylinders at a point just below the bearings for the piston is the passage for communication, *M*, which contains a device, called by the makers a 'regenerator,' *R*. It is simply a series of thin metallic plates, having the edges thickened so as to keep them slightly apart. The

object of the arrangement is to economize heat, by absorbing as much as possible from the hot air discharged from the power cylinder, and in turn parting with a portion of it to the cold air in its passage back from the compression cylinder. It will be understood that the same air is used continuously, being passed back and forth from one to the other of the cylinders, and alternately compressed and heated, and expanded and cooled. Any deficiency of air caused by leakage is supplied by a check-valve, $P$, at the foot of the compression cylinder. The arrangement of the cranks $F\ F$ forms an important consideration, and is an angle of 95°, or 5° in advance of a right angle, for the power crank. After starting the fire and raising the heater to the proper temperature, the engine may be started by simply closing a small pet-cock in the regenerator, and turning the fly-wheel about one revolution or less. The effect is to compress the cold air contained in the compression cylinder to about one-third of its normal volume. After reaching this point, owing to the before-mentioned positions of the cranks, the power piston begins to ascend, while the compression piston in completing the downward stroke forces the air into the heater; and as the displacement in one cylinder is equalized by the receding piston of the other, there is no noticeable change of volume. Owing to the very effective method of heating the compressed air, its temperature is suddenly raised, and the expansion due to the temperature produces a great increase of pressure, which forces the power piston to the end of the up stroke. The compression piston is then 5° behind half stroke and moving upward, when the power piston, by beginning its down stroke, transfers the expanded hot air through the regenerator and water-jacket into the compression cylinder in a thoroughly cool condition, and at or slightly below atmospheric pressure; in the latter case the deficiency is supplied by the check-valve. After passing the upper centre, the compression piston again begins its descent as before. When the engine is to be stopped, it is only necessary to open the pet-cock on the regenerator, which prevents the accumulation of pressure. Where hydrant water is not available, a small force-pump is attached to the compression piston for the purpose of maintaining a circulation around the cylinder. The piston-packing is composed of two rings of leather held down by a gland, that on the power piston being kept cool by the circulation of water around it by means of a pipe connecting with the water-jacket of the compression cylinder."

It has been predicted by more than one prominent engineer that the steam-engine will yet be superseded by the air-engine. In view of what has already been accomplished, the realization of this idea seems by no means impossible, while at the same time it must be confessed that a great deal has yet to be done before the air-engine can successfully compete with its present formidable rival. As the obstacles to the complete success of the air-engine consist chiefly of mechanical difficulties that must be overcome, the case does not seem absolutely hopeless. It is not possible to discuss the subject in the present article as fully as its importance seems to warrant; but the reader who desires to continue his investigations is referred to the following works, from which the foregoing remarks are chiefly compiled: Rankine's "Treatise on the Steam-Engine;" Dr. Barnard's "Report on Machinery and Processes of the Industrial Arts;" *Engineering*, xix.; "Proceedings of the Institution of Civil Engineers," 1845, 1854; and "Transactions of the Institution of Engineers in Scotland," iv. For further works for reference, see ENGINES, HEAT. R. H. B.

ENGINES, DESIGNING OF. The following example illustrates in considerable detail the application of the theoretical considerations given under EXPANSION OF STEAM AND GASES, with their practical modifications, in designing an engine for a given purpose. The example further illustrates the use of the tables in the above-mentioned article. Suppose it is required to design an engine that shall develop 200 net horse-power, it being proposed that the boiler pressure shall be 90 lbs. per square inch above zero, and that the steam shall be cut off when the piston has completed three-tenths of the stroke. The engine is to be non-condensing; the steam is to be cushioned when the piston has completed $\frac{88}{100}$ of the return stroke; the piston speed is to be 600 feet per minute, the stroke 4 feet, and the connecting-rod 10 feet between the centres. While it is impossible to foretell with absolute certainty the performance of a proposed engine, there are various data obtained by previous experience that can be used, since it is reasonable to infer that like causes will produce like effects. It is assumed, then, that the cylinder and port clearance at each end of the stroke will be 6 per cent. of the piston displacement; that the mean back pressure up to the point where cushion commences will be 1 lb. per square inch above the atmosphere, or 15.7 lbs. above zero; that the pressure required to overcome the friction of the working parts of the engine will be 1.6 lb. per square inch; and that the initial pressure in the cylinder will be 4 lbs. less than the boiler pressure, and the pressure at point of cut-off 5 lbs. less than the initial. (Although these allowances are larger than are required for the very best engines, they agree well with ordinary practice, and are, indeed, too small for many of the engines in common use.) Turning to Table VI. in the article EXPANSION OF STEAM AND GASES, it will be seen that the real cut-off for the proposed case is 0.34. The mean total pressure up to the point of cut-off is $[(90-4)+(90-4-5)] \div 2 = 83.5$. By column 2 in Table IV., article EXPANSION OF STEAM AND GASES, the ratio of expansion corresponding to a cut-off of 0.34 is 2.94; and from column 9 in the same table, and a simple calculation, the mean total pressure during the stroke of the piston is determined to be $\frac{83.5}{2.94} + 81 \times 0.367 = 58.1$ lbs. per square inch.

(As calculations of this nature are only approximate, there is no necessity for carrying them beyond one or two decimal places.) The pressure given above is, it will be noticed, the mean total pressure throughout the whole stroke of the piston, including also the pressure in the clearance space; and it must be corrected for the mean back pressure up to the point of cushion, for the clearance and for the cushion. Deducting the back pressure, $58.1 - 15.7 = 42.4$. The correction for clearance is obtained by the formula $p - c \times (P - p)$, where $p$ is the mean total pressure corrected for back pressure, $P$ is the initial pressure, and $C$ is the fraction of clearance. In the present instance, the corrected pressure is $42.4 - 0.06 \times (86 - 42.4) = 39.8$. Calling $d$ the fraction of a stroke uncom-

pleted when cushion commences, and $c$, as before, the fraction of clearance, the ratio of compression is $(d + c) \div c$, or $(0.12 + 0.06) \div 0.06 = 3$, and the final cushion pressure is $15.7 \times 3 = 47.1$. The mean cushion pressure, by column 6 in Table IV., article EXPANSION OF STEAM AND GASES, is $47.1 \times 0.55 = 25.9$. The mean pressure corrected for cushion is $P - c \times (R - 1) \times (p' - p)$; in which expression $P$ is the mean pressure corrected for back pressure and clearance, $c$ is the fraction of clearance, $R$ the ratio of compression, and $p'$ and $p$ the mean and initial cushion pressures respectively. Substituting the proper values in the above formula, the result is the indicated pressure of the proposed engine, or $39.8 - 0.06 \times (3 - 1) \times (25.9 - 15.7) = 38.6$. Subtracting the estimated friction pressure, the mean net pressure is found to be $38.6 - 1.6 = 37$ lbs. per square inch. Having determined the mean net pressure, the diameter of cylinder required can be calculated by the formula, $205 \times \sqrt{\left(\frac{\text{H. P.}}{P \times S}\right)}$, where H. P. is net horse-power, $P$ the mean net pressure in pounds per square inch, and $S$ the piston speed in feet per minute. Hence the diameter of the proposed engine is $205 \times \sqrt{\left(\frac{200}{37 \times 600}\right)} = 19.5$ inches.

If a boiler is to be designed for this engine, some estimate must be formed of the amount of steam that it will use. The examples of the performance of engines of various dimensions, given in the various articles on ENGINES, will greatly assist the designer; but, as a further aid, a method of making an approximate calculation is appended. As the stroke of the engine is 4 feet, and the piston speed is 600 feet per minute, the number of revolutions per hour is $(600 \div 8) \times 60 = 4{,}500$. Suppose that the steam is released when the piston has completed $\frac{95}{100}$ of the stroke; the theoretical pressure at this point is given by the formula $\frac{\frac{1}{R} + c}{x + c} \times P$, where $\frac{1}{R}$ is the apparent cut-off, $c$ the fraction of clearance, $x$ the fraction of stroke for which the pressure is required, and $P$ the pressure at point of cut-off. Hence the pressure when release takes place is $\frac{0.3 + 0.06}{0.95 + 0.06} \times 81 = 28.8$. The weight of a cubic foot of steam of this pressure, by column 10 in Table I. of article EXPANSION OF STEAM AND GASES, is 0.071 lb. The displacement of the piston per revolution to release, including clearance, is 16.76 cubic feet, so that the total weight of steam used per hour, neglecting that saved by cushion, is $16.76 \times 4{,}500 \times 0.071 = 5{,}355$ lbs. As the space filled with cushioned steam at the instant the exhaust-valve closes is 2.82 cubic feet per revolution, and the pressure of the steam at this point is 15.7 lbs. per square inch, the steam saved per hour on account of cushion is $2.82 \times 4{,}500 \times 0.0404 = 513$ lbs.; so that the total steam discharged from the cylinder per hour is $5{,}355 - 513 = 4{,}842$ lbs. (*Note.*—In calculating the piston displacement, the mean piston area, after deducting the cross-section of the piston-rod, should be used when great accuracy is required; but it is scarcely necessary to introduce this element into a preliminary estimate like the above. In making calculations for horse-power or consumption of steam from actual practice, where the indicator cards are furnished, the mean effective piston area should be employed.) To this must be added the steam condensed for the work done during expansion, and the amount condensed on account of the change in temperature to which the interior surfaces of the cylinder are subjected. For the first correction, find what proportion of the total horse-power is developed during the expansion of steam, and multiply this by 1,980,000, the foot-pounds of work in one horse-power per hour. The quotient arising from dividing the latter quantity by 772 gives the units of heat per hour equivalent to the work of expansion, which is to be divided by the latent heat of a pound of steam at the terminal pressure, to reduce it to pounds of water condensed. Thus, the mean total pressure of the steam, as determined above, corrected for clearance, is $58.1 - [0.06 \times (86 - 58.1)] = 56.4$; so that the total horse-power is $(298.65 \times 56.4 \times 600) \div 33{,}000 = 306$. From column 9 in Table IV., article EXPANSION OF STEAM AND GASES, it appears that the portion of the mean total pressure due to expansion is $81 \times 0.367 = 29.7$ lbs. per square inch, so that the total horse-power developed during expansion is $\frac{29.7}{56.4} \times 306 = 161$; and since the latent heat of a pound of steam at the terminal pressure 28.8, as shown in Table I., article EXPANSION OF STEAM AND GASES, column 6, is 941, the steam condensed for work per hour is $(161 \times 1{,}980{,}000) \div (772 \times 941) = 440$. The final allowance for condensation on internal surfaces can only be approximately estimated at between 10 and 15 lbs. of steam per hour per square foot of internal surface. It seems probable that there is some law by which the amount can be definitely determined, when the mean temperatures during forward and return strokes are known; but further investigations are required before the law can be exactly stated. In the present instance, it will be assumed that the condensation is at the rate of 12 lbs. per hour per square foot of internal surface, reckoning the areas of the two heads, both sides of the piston, the cylindrical area, the piston-rod, and the surface of the ports. In the engine under consideration, the surface will be approximately:

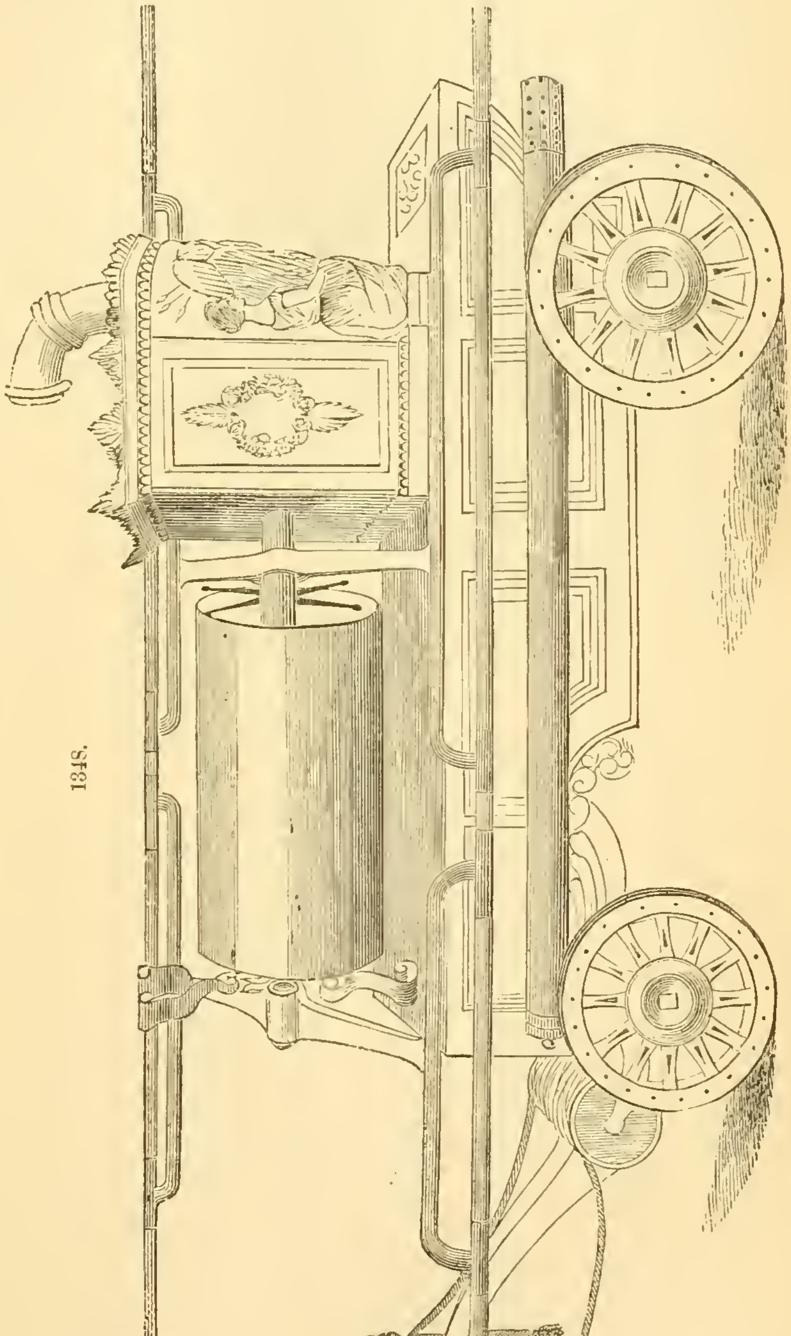
| | | | |
|---|---|---|---|
| In heads and both sides of piston | 8.3 | square | feet. |
| In cylindrical part | 24.3 | " | " |
| In piston-rod | 3.3 | " | " |
| In ports | 12.0 | " | " |
| Total | 47.9 | " | " |

So that the steam condensed per hour will be:

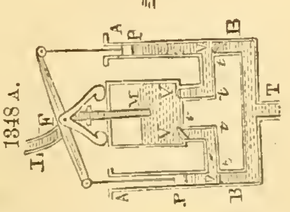
| | |
|---|---|
| $48 \times 12 =$ | 576 |
| Calculated from terminal pressure less cushion | 4,842 |
| Steam condensed for work | 440 |
| Total | 5,858 |

or about 30 lbs. per net horse-power. The method of proportioning a boiler to evaporate this amount of water is explained in the article on Boilers. To reduce the above amount to its equivalent, from and at 212°, as explained when treating of boilers, it is supposed that the feed water is heated by the exhaust steam to a temperature of 180°. Thus, by Tables I. and II., article Expansion of Steam and Gases, the equivalent evaporation for this case will be $5858 \times (1.221 - 0.154) = 6250$ lbs.

If the above calculation had been made for a condensing engine, the only changes required in the data would have been as follows: The mean back pressure up to commencement of cushion would have been assumed at from 3 to 3.5 lbs. per square inch above zero, and the steam condensed on the interior surfaces of the cylinder per hour at from 20 to 25 lbs. per hour per square foot. R. H. B.



1348.



1348 A.

ENGINES, FIRE. The manual engine, Fig. 1348, generally consists of a double forcing-pump communicating with the same air-vessel; and instead of a force-pipe, a flexible leather hose is used, through which the water is driven by the pressure of the condensed air in the air-vessel. Fig. 1348 A represents a section of the apparatus. The pipe $T$ descends into a receiver or vessel containing a supply of water. This pipe communicates with two suction-valves $V$, which open into the pump-barrels of two forcing-pumps $A\ B$, in which solid pistons $P$ are placed. The piston-rods of these are connected with a working-beam $F$, elongated, so that a number of persons may work at both ends of it at once. Force-pipes $t\ t$ proceed from the sides of the pump-barrel above the valves $V$, and they communicate with an air-vessel $M$ by means of forcing-valves $V$, which also open upward. The pipe descends into the air-vessel near the bottom. This pipe is connected with the flexible leathern hose $L$, the length of which is adapted to the purposes to which the machine is to be applied. The extremity of the hose may be carried in any direction, and may be introduced through the doors and windows of buildings. By the alternate action of the pistons, water is drawn through the suction-valve and propelled through the forcing-valves until the air in the top of the vessel $M$ is highly compressed. The pressure acts on the surface of the water in the vessel, and forces it through the leathern hose in a continued stream, so as to spout from its extremity with a force depending partly on the degree of condensation, and partly on the elevation of the extremity of the hose above the level of the engine.

It is to be considered that the pressure of the condensed air has, in the first instance, to support a column of water, the height of which is equal to the level of the end of the tube above the level of the water in the air-vessel; that until the pressure exceeds what is necessary for this purpose, no water can spout from the end of the hose; and, consequently, that the force with which it will so spout will be proportional to the excess of the pressure of the condensed air above the weight of the column of water, the height of which is equal to the elevation of the end of the hose above the level of the water in the air-vessel.

One of the most thorough trials ever made of this class of engines was conducted by a special jury at the International Exhibition held in London in 1862. A summary of these interesting experiments is contained in the tables on page 627.

At the present time manual fire-engines have been almost entirely superseded by the more efficient steam fire-engine, the introduction of which has been largely instrumental in reducing the ravages caused by fire and lessening fire-rates. The earliest steam fire-engine is believed to have been built by John Braithwaite, an Englishman, in 1829, and is described in the *Mechanics' Magazine* for February 13, 1830. Captain Ericsson obtained a medal from the Mechanics' Institute of New York, in 1840, for a design of a steam fire-engine somewhat similar to that produced by Braithwaite; and a steam fire-engine was constructed in 1850 by Mr. Latta of Cincinnati, who has been identified with many important improvements in connection with this machine. Various other builders took up the manufacture of steam fire-engines after Mr. Latta, and they have been gradually developed to the splendid apparatus which is in use to-day.

Several steam fire-engines were exhibited at London in 1862, including one from the United States, and the jury were desirous of investigating their qualities by a very thorough test. Only two of the exhibitors, however, were willing to submit their engines to trial, and these were tested by the jury, with results that are summarized in the two tables that follow, from the data given in the official report:

*Principal Dimensions of Steam Fire-Engines tried at London Exhibition*, 1862.

| | | | |
|---|---|---|---|
| Number of engine | 1 | 2 | 3 |
| Name of maker | Merryweather & Son. | Shand & Mason. | Shand & Mason. |
| Diameter of steam cylinder, inches | 9 | 8.5 | 6.625 |
| " water " " | 6.5 | 7 | 5 |
| Stroke, inches | 15 | 9 | 8 |
| Contents of pump, cubic inches | 968.98 | 676.8 | 314.16 |
| Number of deliveries open on trial | 1 | 2 | 1 |
| Diameter of suction hose, inches | 5 | 3.5 | 3 |
| " of delivery " " | 3 | 3.5 | 2.5 |
| Weight, light, pounds | 8,320 | 7,040 | 4,480 |
| Time of raising pressure to 100 pounds | 12 min. 10 sec. from cold water. | 18 min. 30 sec. from cold water. | 17 min. 40 sec. from warm water. |

*Trial of Steam Fire-Engines at London Exhibition*, 1862.

| NUMBER OF TRIAL. | Number of Engine. | Duration of Trial, in Min. | Duration of Trial, in Sec. | Hose. Length in Feet. | Hose. Diameter of Nozzle, in Inches. | Depth from which Water was drawn, in Feet. | Stream. Horizontal Distance, in Feet. | Stream. Vertical Distance, in Feet. | Stream. True Distance, in Feet. | Stream. Angle from Horizon. | Total Revolutions. | Pressure, in Pounds per Square Inch. Steam. | Pressure, in Pounds per Square Inch. Water. | Delivery, in Fraction of Piston Displacement. | NUMBER OF TRIAL. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 1 | 2 | 15 | 40 | 1.5 | 5 | 60 | 10 | 61 | 10° | ... | 100 | 60 | ... | 1 |
| 2 | | 2 | .. | " | " | " | 60 | 10 | 61 | 10° | 286 | 115 | 60 | .50 | 2 |
| 3 | | 1 | 45 | " | " | " | 60 | 10 | 61 | 10° | 208 | 120 | 45 | .60 | 3 |
| 4 | | 4 | .. | " | 1.38 | " | 80 | 30 | 85 | 21° | 547 | 110 | 75 | .25 | 4 |
| 5 | | 2 | 50 | " | " | " | 80 | 30 | 85 | 21° | 245 | 120 | 75 | .58 | 5 |
| 6 | | 3 | .. | " | " | " | 80 | 30 | 85 | 21° | 378 | 110 | 70 | .22 | 6 |
| 7 | | 3 | .. | " | " | " | 80 | 30 | 85 | 21° | ... | ... | .. | ... | 7 |
| 8 | | 3 | .. | " | " | " | 80 | 30 | 85 | 21° | 386 | 100 | 70 | .21 | 8 |
| 9 | 2 | 2 | 20 | 60 | 1.5 | 5 | 60 | 10 | 61 | 10° | .... | 100 | 60 | .... | 9 |
| 10 | | 1 | .. | " | " | " | 60 | 10 | 61 | 10° | .... | 100 | 60 | .... | 10 |
| 11 | | 1 | 45 | " | " | " | 60 | 10 | 61 | 10° | 435 | 98 | 60 | .47 | 11 |
| 12 | | 1 | 45 | " | " | " | 60 | 10 | 61 | 10° | 429 | 101 | 60 | .42 | 12 |
| 13 | | 3 | .. | " | " | " | 60 | 20 | 63 | 18° | 714 | 120 | 58 | .34 | 13 |
| 14 | | 3 | .. | " | " | " | 60 | 20 | 63 | 18° | 618 | 90 | 40 | .25 | 14 |
| 15 | | 3 | .. | " | 1.38 | " | 80 | 20 | 82 | 14° | 486 | 110 | 90 | .45 | 15 |
| 16 | | 5 | 55 | " | " | " | 80 | 20 | 82 | 14° | 989 | 100 | 90 | .41 | 16 |
| 17 | | 4 | .. | " | " | " | 80 | 30 | 85 | 21° | 538 | 110 | 80 | .37 | 17 |
| 18 | | 10 | 40 | " | " | " | 100 | 20 | 102 | 11° | 1,581 | 105 | 110 | .26 | 18 |
| 19 | | 63 | .. | " | " | " | 100 | 30 | 104 | 17° | 9,840 | 90 | 90 | .05 | 19 |
| 20 | 3 | 3 | .. | 40 | 1 | 5 | 60 | 10 | 61 | 10° | 599 | 122 | 67 | .65 | 20 |
| 21 | | 1 | 30 | " | " | " | 60 | 10 | 61 | 10° | 306 | 112 | 83 | .56 | 21 |
| 22 | | 3 | .. | " | " | " | 60 | 20 | 63 | 18° | 625 | 135 | 100 | .63 | 22 |
| 23 | | 3 | .. | " | " | " | 60 | 20 | 63 | 18° | 581 | 137 | 85 | .53 | 23 |
| 24 | | 3 | .. | " | .88 | " | 80 | 20 | 82 | 14° | 534 | 170 | 103 | .30 | 24 |
| 25 | | 10 | 55 | " | " | " | 80 | 20 | 82 | 14° | 1,011 | 125 | 100 | .27 | 25 |
| 26 | | 4 | .. | " | " | " | 80 | 30 | 85 | 21° | 690 | 125 | 95 | .18 | 26 |
| 27 | | 2 | 50 | " | " | " | 80 | 30 | 85 | 21° | 630 | 127 | 100 | .18 | 27 |
| 28 | | 3 | .. | " | " | " | 80 | 30 | 85 | 21° | 570 | 127 | 100 | .07 | 28 |
| 29 | | 3 | .. | " | " | " | 80 | 30 | 85 | 21° | 511 | 130 | 100 | .16 | 29 |
| 30 | | 3 | .. | " | " | " | 80 | 30 | 85 | 21° | 435 | 120 | 90 | .03 | 30 |
| 31 | | 10 | 40 | " | " | " | 100 | 20 | 102 | 11° | 1,790 | 120 | 95 | .02 | 31 |

*Principal Dimensions of Manual Engines tried at London Exhibition,* 1862.

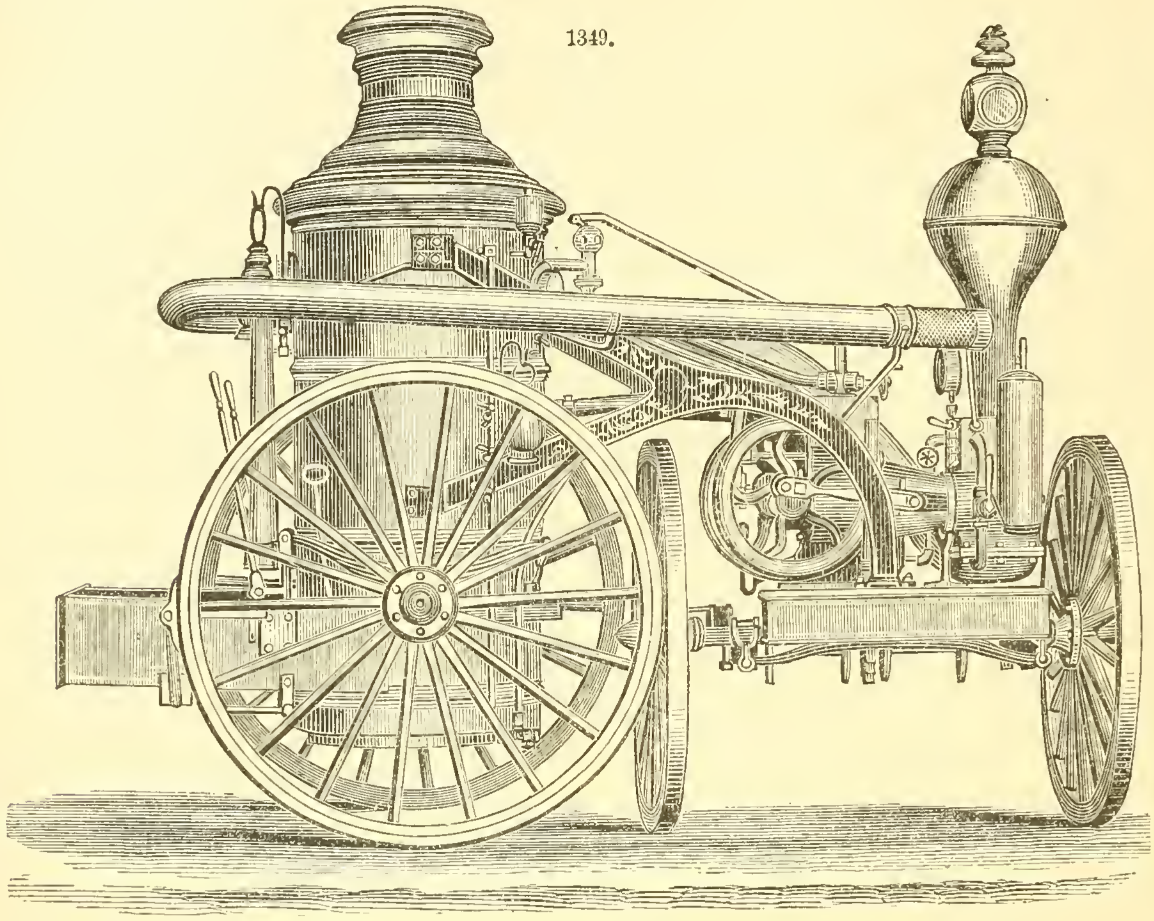
| NUMBER OF ENGINE. | NAME. | PUMPS. | | | Stroke of Handles, in Inches. | DIAMETER OF HOSE, IN INCHES. | |
|---|---|---|---|---|---|---|---|
| | | Diameter, in Inches. | Stroke, in Inches. | Contents, in Cubic Inches. | | Suction. | Delivery. |
| 1 | Shand & Mason. London Brigade pattern............ | 7 | 8 | 615.74 | 33.5 | 2.75 | 2.5 |
| 2 | Merryweather & Son, London Brigade pattern....... | 7 | 8 | 615.74 | 34 | 3 | 2.5 |
| 3 | Rose, Manchester Brigade pattern.................... | 7 | 8.1 | 623.44 | 31.5 | 3 | 2.13 |
| 4 | Merryweather & Son, London (Hodge's Testimonial). | 7 | 8 | 615.74 | 34 | 3 | 2.5 |
| 5 | Shand & Mason, Military pattern.................... | 6 | 8 | 452.38 | 42.5 | 3 | 2.5 |
| 6 | Merryweather & Son, Country Brigade pattern....... | 6 | 8.2 | 463.69 | 31.1 | 2.5 | 2.5 |
| 7 | Roberts, double action.............................. | 9.5 | 3.4 | 487.31 | 38 | 3 | 2.5 |
| 8 | Blinkhorn & Co., double action...................... | 7 | 8 | 615.74 | 36 | 3 | 2.5 |
| 9 | Shand & Mason......................................... | 9 | 8 | 1,017.87 | 34.1 | 3.5 | 2.5 |
| 10 | Broughton Copper Co., Manchester Brigade pattern.. | 7 | 8.4 | 642.68 | 31.3 | 3.5 | 2.5 |
| 11 | Letestu, Breveté (French)........................... | 4.6 | 7 | 231 | 30 | 3 | 2 |

*Summary of Trials of Manual Engines at London Exhibition,* 1862.

| NUMBER OF TRIAL. | Number of Engine. | Duration of Trial, in Seconds. | HOSE. | | Depth from which Water was drawn, in Feet. | STREAM. | | | | Total Number of Strokes. | Delivery, in Fraction of Piston Displacement. | Number of Men. | NUMBER OF TRIAL. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Length in Feet. | Diameter of Nozzle, in Inches. | | Horizontal Distance, in Feet. | Vertical Distance, in Feet. | True Distance, in Feet. | Angle from Horizon. | | | | |
| 1 | 1 | 30 | 40 | Open delivery. | 5 | .. | .. | .. | .. | 27 | 1.03 | 28 | 1 |
| 2 | | 30 | " | " " | " | .. | .. | .. | .. | 33 | .96 | " | 2 |
| 3 | | 30 | " | " " | " | .. | . | .. | .. | 30 | .97 | " | 3 |
| 4 | | 180 | " | .875 | " | 20 | 20 | 28 | 45° | 180 | .81 | " | 4 |
| 5 | | 180 | " | " | " | 20 | 30 | 86 | 56° | 195 | .84 | " | 5 |
| 6 | | 180 | " | " | " | 40 | 20 | 44 | 26° | 188 | .78 | " | 6 |
| 7 | | 120 | " | " | " | 40 | 30 | 50 | 37° | 136 | .63 | " | 7 |
| 8 | | 120 | " | " | " | 60 | 20 | 63 | 18° | 137 | .53 | " | 8 |
| 9 | | 120 | " | .8125 | " | 60 | 25 | 65 | 23° | 135 | 50 | " | 9 |
| 10 | 2 | 30 | 40 | Open delivery. | 5 | .. | .. | .. | .. | 34 | 1.05 | 28 | 10 |
| 11 | | 30 | " | " " | " | .. | .. | .. | .. | 38 | .97 | " | 11 |
| 12 | | 30 | " | " " | " | .. | .. | .. | .. | 31 | 1.13 | " | 12 |
| 13 | | 180 | " | .875 | " | 20 | 20 | 28 | 45° | 180 | .78 | " | 13 |
| 14 | | 180 | " | " | " | 20 | 30 | 36 | 56° | 183 | .80 | " | 14 |
| 15 | | 180 | " | " | " | 40 | 20 | 44 | 26° | 198 | .73 | " | 15 |
| 16 | | 120 | " | " | " | 40 | 30 | 50 | 37° | 129 | .62 | " | 16 |
| 17 | | 120 | " | " | " | 60 | 20 | 63 | 18° | 126 | .35 | " | 17 |
| 18 | | 120 | " | ·8125 | " | 60 | 25 | 65 | 23° | 114 | .31 | " | 18 |
| 19 | 3 | 30 | 40 | Open delivery. | 5 | .. | .. | .. | .. | 31 | .94 | 28 | 19 |
| 20 | | 30 | " | " " | " | .. | .. | .. | .. | 33 | .92 | " | 20 |
| 21 | | 30 | " | " " | " | .. | .. | .. | .. | 30 | .90 | " | 21 |
| 22 | | 180 | " | .875 | " | 20 | 20 | 28 | 45° | 167 | .75 | " | 22 |
| 23 | | 180 | " | " | " | 20 | 30 | 36 | 56° | 192 | .66 | " | 23 |
| 24 | 4 | 120 | 40 | .875 | 5 | 60 | 20 | 63 | 18° | 130 | .58 | 28 | 24 |
| 25 | | 120 | " | " | " | 60 | 20 | 63 | 18° | 127 | .59 | " | 25 |
| 26 | | 120 | " | .8125 | " | 60 | 25 | 65 | 23° | 116 | .43 | " | 26 |
| 27 | 5 | 60 | 40 | Open delivery. | 5 | .. | .. | .. | .. | 63 | 1.06 | 12 | 27 |
| 28 | | 60 | " | " " | " | .. | .. | .. | .. | 65 | 1.04 | " | 28 |
| 29 | | 120 | " | .75 | " | 20 | 20 | 28 | 45° | 124 | .93 | 20 | 29 |
| 30 | | 180 | " | " | " | 40 | 20 | 44 | 26° | 143 | .86 | 10 | 30 |
| 31 | | 180 | " | " | " | 40 | 20 | 44 | 26° | 143 | .82 | " | 31 |
| 32 | 6 | 60 | 40 | Open delivery. | 5 | .. | .. | .. | .. | 76 | .98 | 12 | 32 |
| 33 | | 45 | " | " " | " | .. | .. | .. | .. | 56 | 1.02 | " | 33 |
| 34 | | 60 | " | " " | " | .. | .. | .. | .. | 55 | 1.23 | " | 34 |
| 35 | | 120 | " | .75 | " | 20 | 20 | 28 | 45° | 129 | .86 | 20 | 35 |
| 36 | | 180 | " | " | " | 40 | 20 | 44 | 26° | 148 | .77 | 10 | 36 |
| 37 | | 180 | " | " | " | 40 | 20 | 44 | 26° | 151 | .75 | " | 37 |
| 38 | 7 | 60 | 40 | Open delivery. | 5 | .. | .. | .. | .. | 57 | 1.14 | 20 | 38 |
| 39 | | 60 | " | " " | " | .. | .. | .. | .. | 60 | 1.10 | " | 39 |
| 40 | 8 | 180 | 60 | .75 | 5 | 40 | 20 | 44 | 26° | 99 | .73 | 10 | 40 |
| 41 | 9 | 180 | 40 | 1 | 5 | 40 | 20 | 44 | 26° | 160 | .77 | 45 | 41 |
| 42 | | 180 | " | " | " | 40 | 30 | 50 | 37° | 162 | .72 | " | 42 |
| ·43 | 10 | 180 | 75 | .875 | 5 | 40 | 20 | 44 | 26° | 170 | .70 | 28 | 43 |
| 44 | | 180 | " | " | " | 40 | 30 | 40 | 37° | 145 | .63 | " | 44 |
| 45 | 11 | 180 | 30 | .5625 | 5 | 40 | 20 | 44 | 26° | 178 | .67 | 12 | 45 |
| 46 | | 180 | " | " | " | 40 | 30 | 50 | 37° | 198 | .39 | " | 46 |

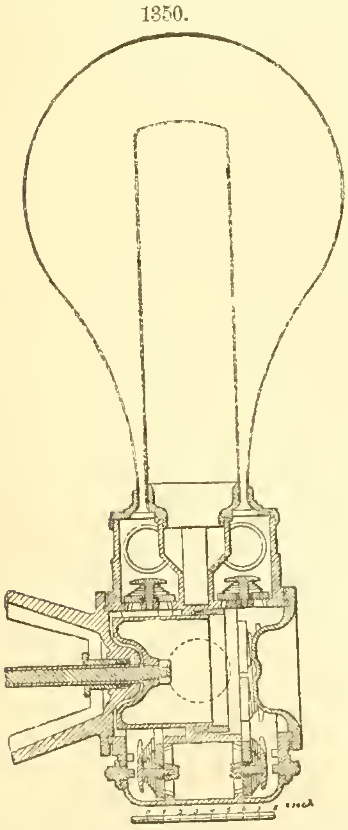
A valuable paper, containing details of these and other steam fire-engines, together with a historical account and an extended discussion, may be found in the "Transactions of the Society of Engineers for 1863."

1349.



The steam fire-engines representing the present practice in the United States may be classed as reciprocating engines and pumps without fly-wheels, reciprocating engines and pumps with fly-wheels (this class being subdivided into engines with cranks and connecting-rods, and engines with yoke motion), and rotary engines and pumps. Representatives of all but the first class, which differs but little from the ordinary direct-acting pump, are illustrated and described in the following pages.

1350.

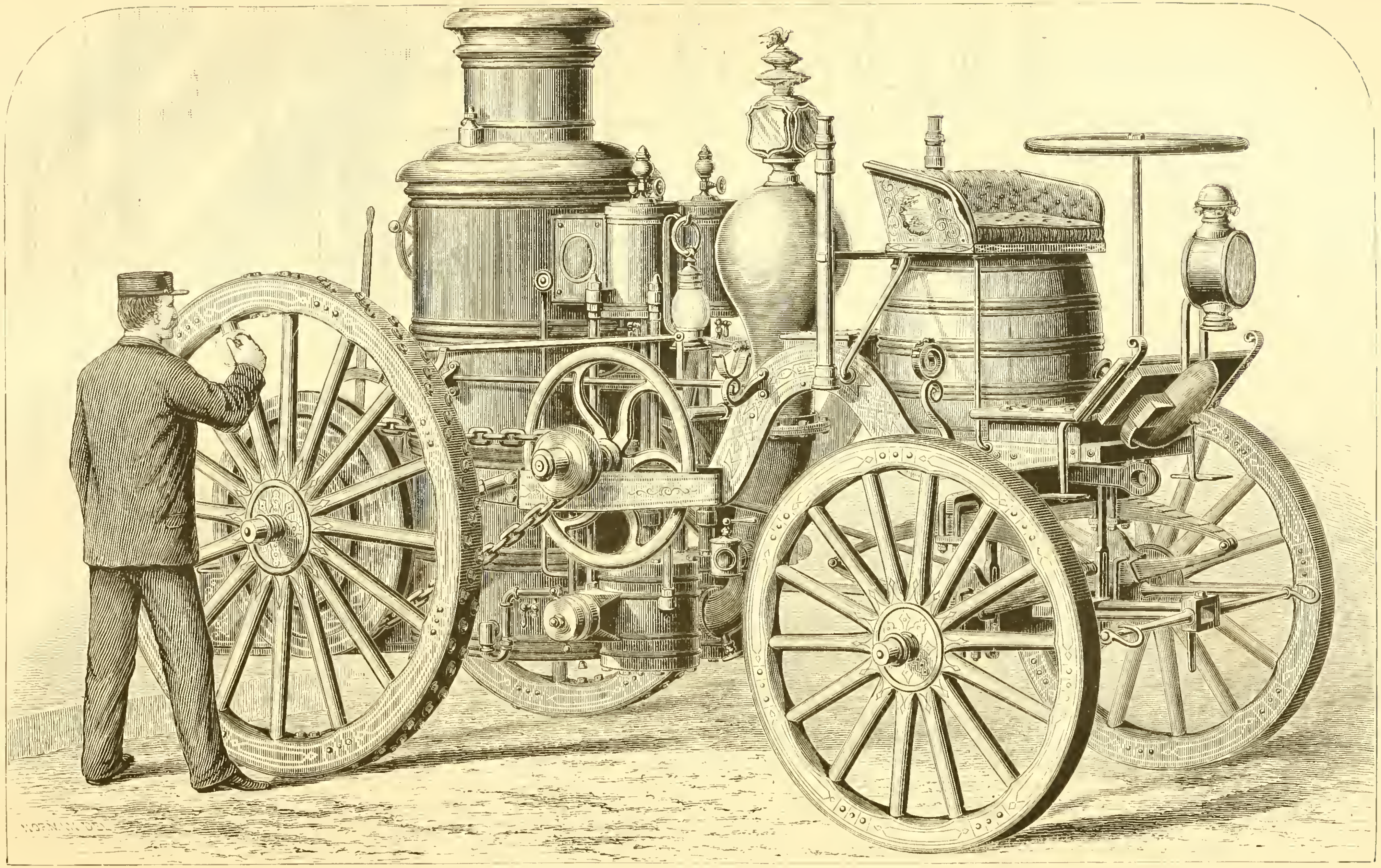


The Button engine, Fig. 1349, has two fly-wheels and the ordinary direct-acting engine connection, the pump-piston being attached to the cross-head. Fig. 1350 is a sectional view of the pump, which requires no explanation. The boiler is of the vertical fire-tube variety.

The Gould engine, shown in section in Fig. 1351, has a vertical fire-tube boiler, with a submerged smoke-flue. The sides of the fire-box are tapering, for the purpose of increasing the area of the grate and promoting the water circulation. The pump-cylinder can be removed by taking off the bottom cover, so that the valves can be examined and repaired.

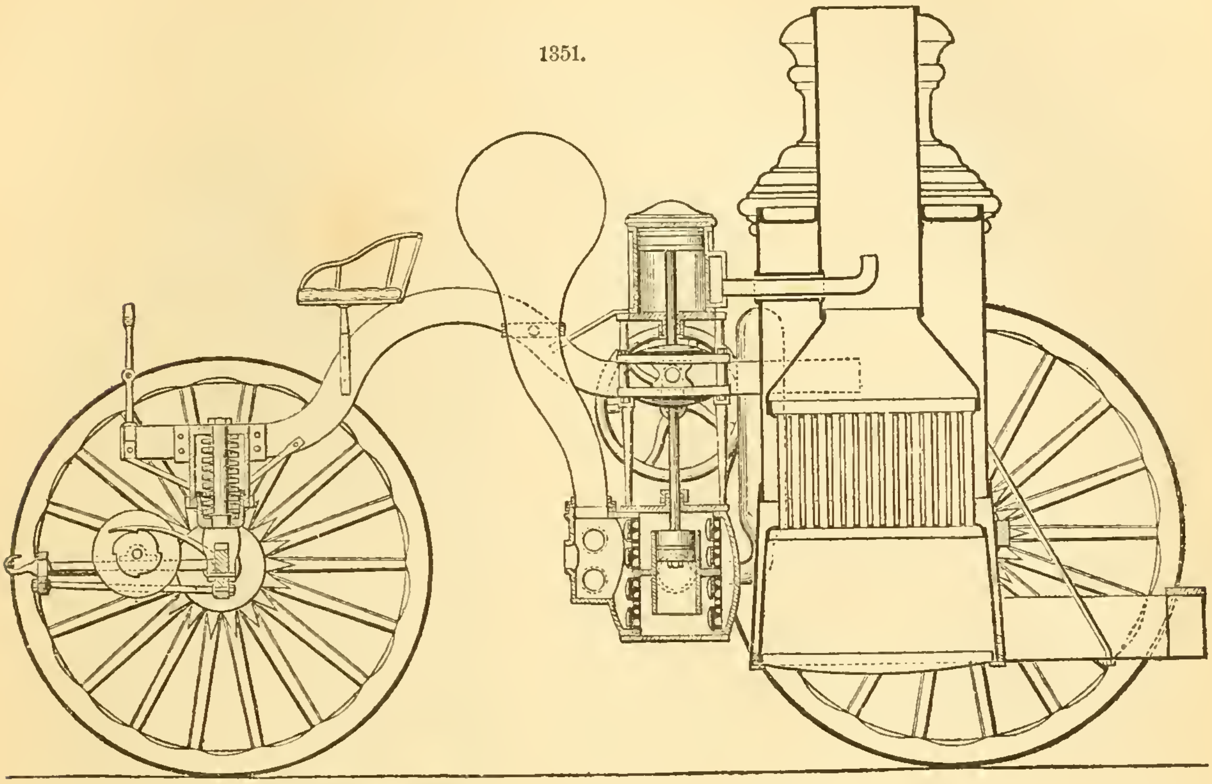
The Silsby fire-engine, represented in Figs. 1352, 1353, 1354, and 1355, has been selected as a representative of the rotary class. The engine, Fig. 1353, consists of two toothed wheels running together in a steam-tight case. The steam is admitted at *A* and exhausted at *B*, thus moving the wheels. The long teeth of these cams, which are intended to work steam-tight against the sides and periphery of the case, are packed with metallic blocks which are pressed outward by springs. There are openings in the sides of the case for the purpose of removing and replacing the packing-blocks, when necessary. The pump, Fig. 1354, is in the same line with the engine, and is similar in construction. There are outside gears between the engine and pump, which act as guides. The boiler, Fig. 1355, contains both fire- and water-tubes, the latter being secured to the lower tube-sheet and extending into the furnace. Each water-tube has a smaller tube within it, for the purpose of assisting circulation, and superheating the steam by passing it, as formed, through the annular spaces between the internal and external tubes.

The Amoskeag self-propelling engine is shown in a full-page engraving, and a general sectional view in Fig. 1356. Special facilities for the examination of this engine have been afforded by Chief Engineer Eli Bates, of the New York City Fire Department;

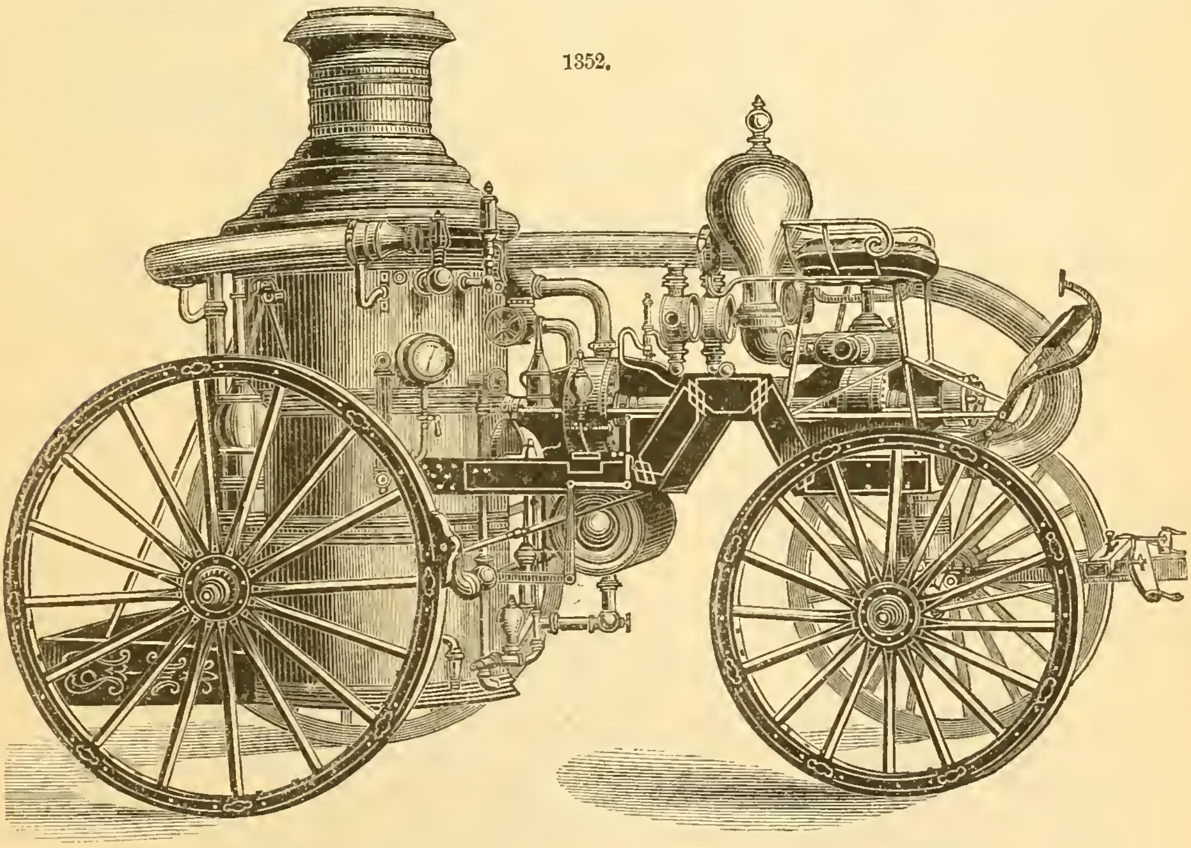


AMERICAN STEAM FIRE-ENGINE.

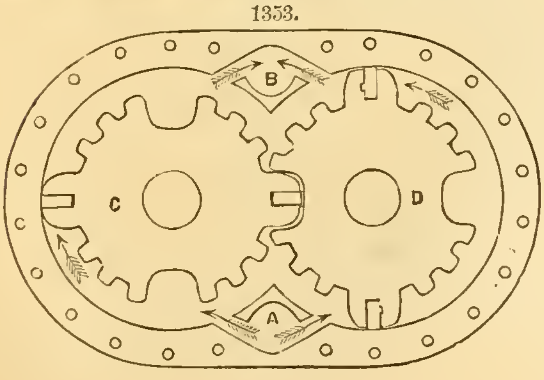
1351.



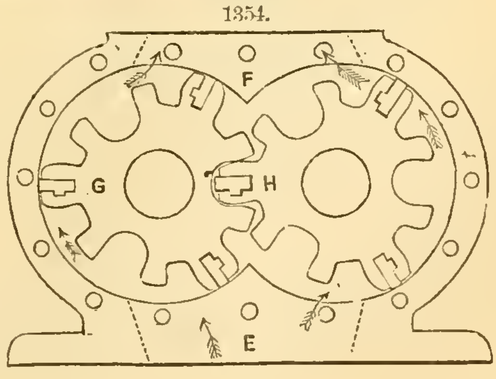
1352.



1353.

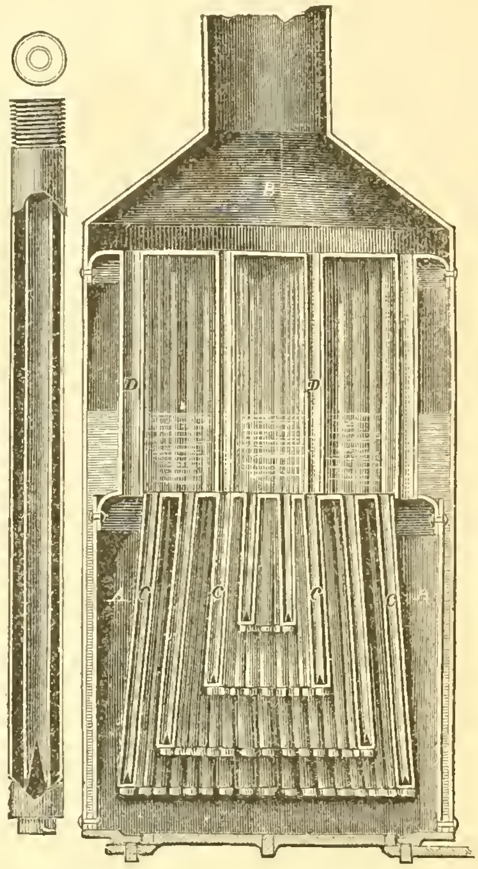



1354.



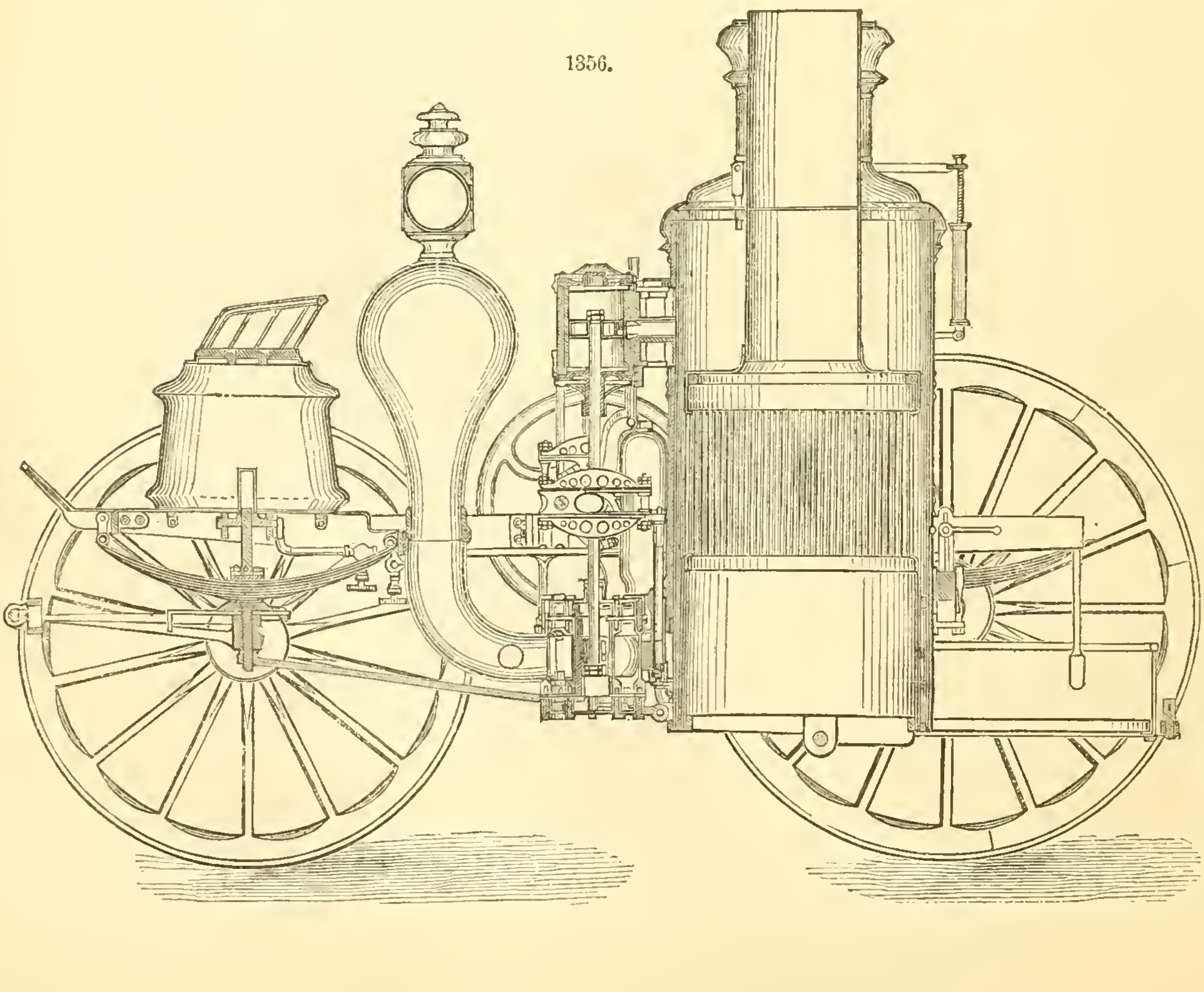
and the writer is indebted to him, and to the officers and men of the department, for many courteous attentions. A somewhat detailed description of this engine is appended, and it may be noted that many of the features described are to be found in the other styles of engines. These fire-engines are made both self-propelling, in which case two engines are always used, and with a pole for horses, engines of this class being made single or double, as may be desired. In the self-propelling engines, as will be seen by reference to the full-page plate, there is a pulley on the fly-wheel shaft, which communicates motion to a pulley on the back driving-axle through a chain connection. The first pulley is secured to the fly-wheel shaft by a spring key, which is readily withdrawn when it is desired to work the pumps, and the pulley then remains stationary on the revolving shaft, without any tendency to produce motion in the back driving-axle. The engines are fitted with link-motion, so that they can readily be reversed. It will be seen that there is an upright shaft with a large hand-wheel at the end, directly in front of the wheelsman's seat. There is a gear-wheel on the other end of this shaft, which works in a rack connected to the front driving-axle, thus enabling the wheelsman to guide the engine in any direction. In passing around a curve, it is evident that one of the back driving-wheels must travel faster than the other, and provision is made for this by an attachment commonly known as the "differential gear." The wheel on the back axle that is nearest to the pulley over which the driving-chain passes is loose on the axle. The pulley over which the driving-chain passes is also loose on the axle, but it has within it a wheel carrying two bevel-pinions on the periphery, which work in two bevel-gears secured to the loose wheel and the driving-axle respectively. This arrangement allows the loose wheel to slip when the resistance to motion is unequally distributed between the two back wheels. (A clear illustration of this "differential gear" may be found in a paper on "Traction Engines," by Prof. Thurston, published in the *Journal of the Franklin Institute* for January, 1873.)

1355.



The boiler of this engine has vertical fire-tubes, and needs no particular description, being clearly

1356.



illustrated in Fig. 1356. The pump-valves are circular disks of rubber, with light spiral springs above them, and are so arranged that the seats can be easily removed. The pump-plunger is packed with two cup-leathers. The pump has a relief-valve, which can be set to any pressure by turning a hand-wheel, and will thus control the water-pressure which the hose sustains. It frequently happens that the fireman has to go with the nozzle into the interior of a burning building, and, having subdued the fire, desires to stop the water before wetting valuable goods. The nozzles used in the New York Fire Department are fitted with valves, which can be closed when desired, cutting off the discharge instantly; and the relief-valve allows this to be done without injury to the hose or other connections. Below the wheelsman's seat, as seen in Fig. 1356, is a tank, holding about a boilerful of fresh water, from which the supply for feeding the boiler is drawn when salt water is being forced by the pumps, and which also furnishes a supply when the engine is proceeding to a fire at a distance. When the engine is drawing water from a hydrant, the boiler feed-pumps can also be supplied from the same source.

Simple arrangements are provided for chocking the springs, in order to prevent vibrations when the pumps are in action. The fuel used for generating steam is cannel coal, which, when put into the furnace in large lumps, burns freely and without forming clinker. An engine ordinarily carries sufficient coal for a continuous run of an hour or a little more. When standing in the engine-house, a pressure of about 80 lbs. per square inch is maintained in the boiler of the self-propelling engine, and about 5 lbs. in the boilers of engines that are drawn by horses. This pressure is maintained by connecting the boiler of the fire-engine with a small circulating boiler located in the engine-house, the connecting pipes being so arranged that there is a constant circulation of water. In the case of an engine drawn by horses, the circulating boiler is of the simplest description, consisting of a coil of pipe in the fire-box of an ordinary coal-stove. When the engine is taken from the house, an automatic arrangement shuts the valves connecting the circulating pipes with the boiler of the fire-engine, and opens communication with a tank, through which the circulation continues. The limits of this article will not permit mention of the many ingenious contrivances that have been developed since the telegraph has been taken into the service by the fire department, but the reader will find an excellent popular description of the most advanced practice in *Harper's Magazine* for October, 1877.

The principal dimensions of the engines that have been described are given in the accompanying table:

*Table showing Dimensions of American Steam Fire-Engines.*

| DETAILS. | Button Engine Works. | B. S. Nichols & Co. | Silsby Manufacturing Company. | Amoskeag Manufacturing Company. | |
|---|---|---|---|---|---|
| | | | | Old Pattern. | Self-propelling. |
| Length, with tongue removed, feet | 12.5 | 12 | 12.5 | 12 | 16 |
| Width, feet | 6.1 | | 6 | 5.83 | 6.25 |
| Height, feet | 9 | 8 | 9.17 | 8.33 | 9.25 |
| Weight, light, lbs | 5,500 | 4,400 | 5,200 | 6,000 | 8,700 |
| " equipped, lbs | 6,100 | 5,000 | 5,550 | 6,500 | 9,500 |
| Diameter of boiler, inches | 39.5 | 31.5 | 36 | 31 | 33 |
| Height of boiler, feet | 5 | 4.67 | 4.67 | 5.33 | 5.42 |
| Grate surface, square feet | 7.46 | 5.58 | 5.5 | 4.28 | 4.91 |
| Number of tubes | 480 | 309 | 260 | 250 | 311 |
| External diameter of tubes, inches | 1.25 | 1.25 | 2, and 1.25 | 1.25 | 1.25 |
| Length of tubes, inches | 20 | 14 | 22 | 18 | 18 |
| Cross area of tubes, square feet | 3.202 | 2.062 | .937 | 1.668 | 2.075 |
| Heating surface in fire-box, square feet | 35.77 | | 28 | 6 | 7 |
| Total heating surface, square feet | 297.6 | 228.4 | 218 | 171 | 207 |
| Ratio of heating to grate surface | 40 | 40.9 | 39.6 | 39.8 | 42.3 |
| " of tube area " " | 0.428 | 0.369 | 0.170 | 0.388 | 0.424 |
| Height of chimney above grate, feet | 7.42 | 6.67 | 7.83 | 6 | 7.5 |
| Water space, cubic feet | 8 | 2.56 | 5 | 6.78 | 7.2 |
| Steam " " " | 12 | 7.27 | 6 | 6.81 | 7.66 |
| Number of engines | 1 | 1 | 1 | 1 | 2 |
| Diameter of steam cylinder, inches | 14 | 9 | 11 | 6 | 8 |
| Length of stroke, inches | 4.5 | 7 | 4.75 wide | 8 | 8 |
| Number of pumps | 1 | 1 | 1 | 1 | 2 |
| Diameter of pump, inches | 8 | 6 | 7.25 | 4 | 4.5 |
| Stroke " " | 4.5 | 7 | 4.5 wide | 8 | 8 |
| Capacity of air-chamber, cubic feet | 5.5 | 2.4 | 2.75 | 2.25 | 2.25 |
| Number of discharge orifices | 4 | 3 | 2 | 2 | 2 |
| Diameter " " inches | 2.5 | 2.5 | 2.5 | 2.5 | 2.5 |
| Number of suction " | 1 | 2 | 1 | 2 | 2 |
| Diameter " " inches | 4.5 | 4.5 | 4 | 5 | 5 |

There are but few records of trials made with modern fire-engines by competent experts; and although the catalogues of the various builders are filled with testimonials, they are but feeble aids for the formation of a critical opinion. Some points of interest were developed in the trial of fire-engines at the Centennial Exposition of 1876, and a summary of the same, from the official report, is given in the following table. The trials were conducted by Wellington Lee, under the instructions of the Committee of Judges, Messrs. Charles T. Porter, Joseph Belknap, and E. Brugsch. Mr. Lee says in his report: "A careful analysis of the facts brought out at the trials will justify the theory upon which the programme and rules were made, viz.: the engine that is capable, at a fire, of exerting the greatest amount of power in proportion to its weight (other things being equal), is the best."

*Summary of Fire-Engine Tests at International Exposition*, 1876.

| NUMBER FOR REFERENCE. | NAME. | WEIGHT IN POUNDS. | | | Diameter of Steam Cylinder. | Diameter of Water Cylinder. | Stroke. | Ratio of Steam to Water Cylinder. | BOILER. | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Light. | With Water. | Equipped. | | | | | Diamcter. | Height. | Heating Surface. |
| | | | | | Inches. | Inches. | Inches. | | Inches. | Inches. | Sq. Ft. |
| 1 | Silsby........... | 6,596 | 7,045 | 8,173 | 13.5, 6.25 | 8.38, 5.25 | .. | .... | 40 | 60 | 330 |
| 2 | " .......... | 4,795 | 5,140 | .... | .... | .... | .. | .... | 36 | 56 | 197 |
| 3 | Nichols......... | 7,122 | 7,323 | .... | 9 | 6 | 7. | 2.25 | 40 | 60 | 251 |
| 4 | La France....... | 7,061 | 7,355 | 8,310 | .... | .... | .. | .... | 40 | 56 | 265 |
| 5 | Ronald.......... | 5,812 | 6,022 | .... | 7.75 | 4.33 | 9 | 3.2 | 32 | 56 | ... |
| 6 | Clapp & Jones... | 3,310 | 3,505 | .... | 7 | 4.25 | 7 | 2.71 | 28 | 52 | 123 |
| 7 | " ... | 6,503 | 6,825 | 7,847 | 8 | 4.63 | 8 | 2.99 | 38 | 58 | 248 |
| 8 | Button.......... | 5,035 | 5,225 | .... | 12 | 8, 6.75 | 4.5 | 2.25, 3.16 | 34.5 | 60 | 190 |
| 9 | Amoskeag...... | 7,522 | 8,920 | .... | 7.625 | 4.5 | 8 | 2.87 | 31.8 | 64 | 175 |
| 10 | " ...... | 6,105 | 6,264 | .... | 6.875 | 4.25 | 8 | 2.62 | 30.5 | 61 | 151 |
| 11 | Clapp & Jones... | 3,925 | 4,098 | .... | 8 | 4.875 | 8 | 2.69 | 32 | 52 | 147 |

| NUMBER FOR REFERENCE. | Area of the Four Axle Journals. | Total Time of Trial. | PRESSURE IN POUNDS PER SQUARE INCH. | | Average Diameter of Nozzle. | STREAM THROWN. | | CONSUMPTION OF STORES. | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Steam. | Water. | | Vertical Height. | Horizontal Distance. | Coal. | Wood. | Oil. | Tallow. |
| | Sq. In. | Minutes. | | | Inches. | Feet. | Feet. | Pounds. | Pounds. | Gallons. | Pounds. |
| 1 | 25.9 | 684.5 | 83.0 | 139.6 | 1.46 | 174.7 | 203.4 | 10,880 | 275.75 | } 5 | .... |
| 2 | 16.5 | " | 64.9 | 108.5 | 1.2 | ..... | 187.4 | 4,212 | 193 | | .... |
| 3 | 31.4 | 525.5 | 109.7 | 82.1 | 1.47 | ..... | 202.9 | 6,581 | 194 | .25 | .... |
| 4 | 28.3 | 512.5 | 62.8 | 78.9 | 1.46 | ..... | 47.7 | 8,054 | 240.25 | 2.5 | .... |
| 5 | 21.7 | 515.5 | 67.7 | 64.1 | 1.32 | ..... | 27.2 | 4,889.5 | 211.25 | .19 | .... |
| 6 | 15.9 | 684.5 | 84.9 | 119 | 1.01 | ..... | 182.4 | 2,686 | 173.5 | .33 | 1.25 |
| 7 | 28.3 | " | 90.1 | 157.1 | 1.41 | 202.3 | 215.2 | 8,715 | 280.75 | .67 | 1.25 |
| 8 | 21.3 | 52 | 65.6 | 83.2 | 1.24 | ..... | ..... | 287.5 | 65 | .13 | .... |
| 9 | 24 | ..... | .... | .... | .... | ..... | ..... | ....... | ...... | .... | .... |
| 10 | 23.5 | ..... | .... | .... | .... | ..... | ..... | ....... | ...... | .... | .... |
| 11 | 15.9 | 576.5 | 100.7 | 145.5 | .96 | 192.3 | 160.4 | 4,099 | 173.25 | .5 | 1.25 |

See also FIRE-EXTINGUISHERS. R. H. B.

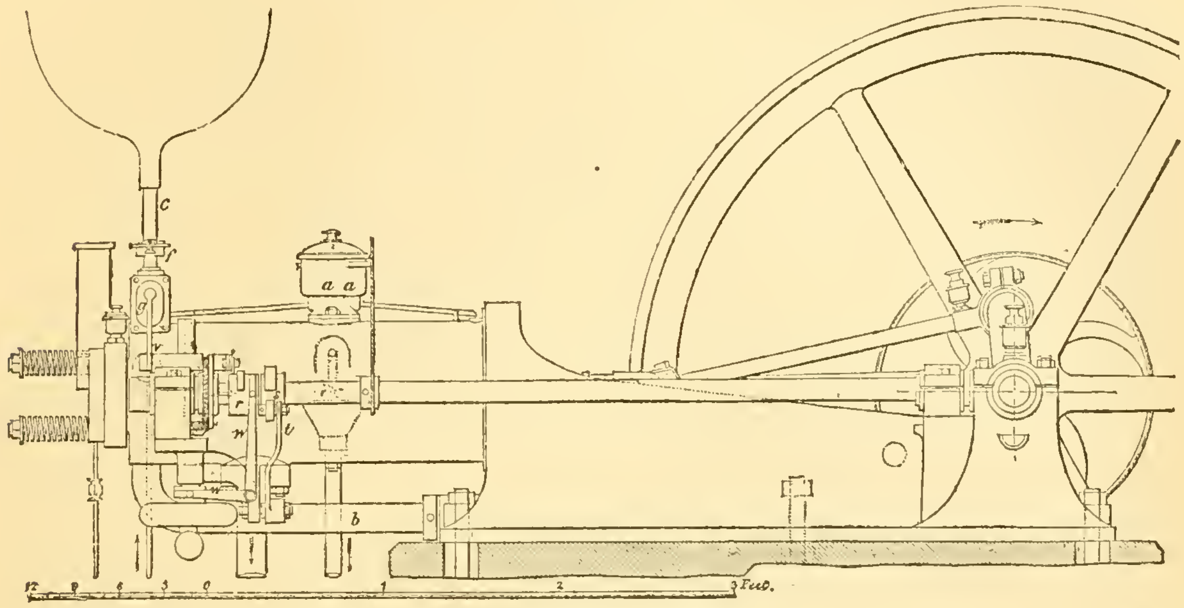
ENGINES, GAS AND VAPOR. The majority of engines of this character have been designed to use an inflammable gas to which sufficient air has been added to form an explosive compound, and thus produce the requisite pressure. The energy is produced at the moment needed, and there is no storing up of heat. Hence it will be seen that the gas-engines find a special applicability in cases where continuous work is not required. Descriptions of many prominent varieties of this class of engines, together with a historical account, may be found in Dr. Barnard's "Report on the Machinery and Processes of the Industrial Arts."

The great difficulty in the way of constructing a satisfactory gas-engine * has always arisen from the suddenness of the explosion and expansion which has to be utilized. In the Otto and Langen engine this difficulty was surmounted very ingeniously by allowing the expansion to take place under a free piston, whose velocity was not limited by the motion of a crank, and engaging the piston-rod with the driving-shaft only on its downward stroke. In this way the sudden expansion could of course be more completely utilized than in any case where the velocity of the piston was controlled by the usual connection to a crank-shaft, but at the same time the whole arrangement had very distinct drawbacks, and was obviously open to improvement. In Herr Otto's later arrangement the difficulty arising from the suddenness of the explosion is removed in a totally different way, viz., by making it less sudden. This could not be done previously because the mixture of air and gas was always drawn into the cylinder at atmospheric pressure, and was already used as dilute as was possible under these conditions. If only, however, the mixture could be used under pressure, a much larger dilution of air could be employed without destroying its explosiveness, and in consequence the violence and rapidity of the explosion would be very much reduced. It is upon this principle that the engine is constructed; the sudden explosion has been reduced to what is really not much more than a rapid combustion and expansion—not too rapid to allow it to be used, without loss, at the beginning of the stroke of an engine arranged with connecting-rod and crank in the usual way. In general external appearance the engine resembles a small horizontal engine, but the resemblance is only superficial. The cylinder is single-acting, open at the front end, and is so arranged that it only completes its cycle of operations once in two complete double strokes. Its method of working is as follows: The piston in moving forward draws into the cylinder a mixture of air and coal-gas, the latter in measured quantity; returning, it compresses this mixture into little more than one-third of its volume, as drawn in at atmospheric pressure; these two operations take up one complete double stroke. As the piston is ready to commence the next stroke the compressed mixture is ignited, and, expanding, drives the piston before it, while in the second return stroke the burnt gases are expelled from the cylinder, and the whole made ready to start afresh. Work is actually being done on the piston, therefore, only during one-quarter of the time it is in motion, the gearing, as well as the work driven, being carried forward by the fly-wheel during the rest of the time.

* *Engineering*, xxvi., 155.

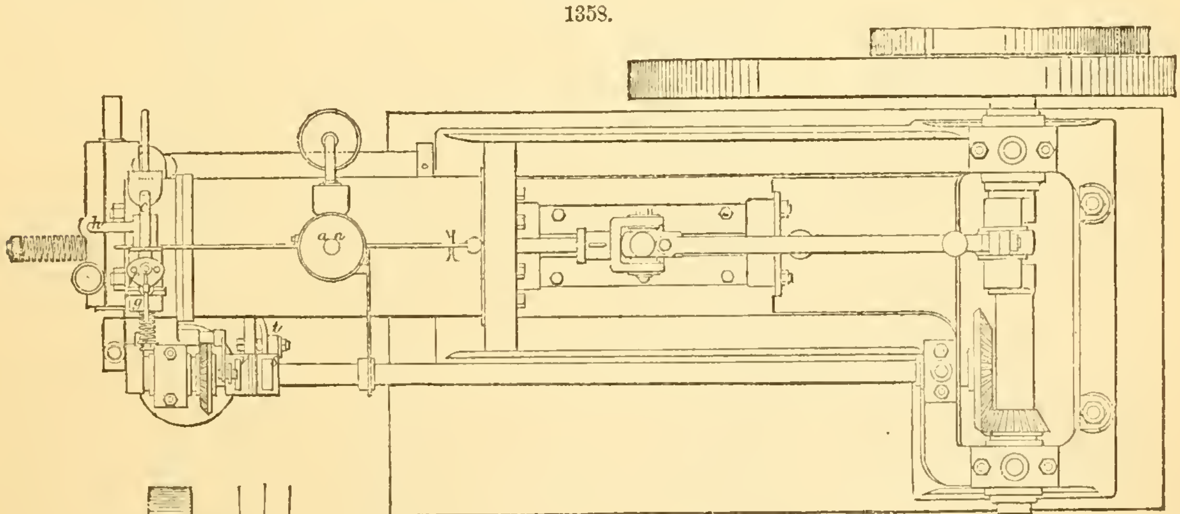
Figs. 1357, 1358, and 1359 are elevation, plan, and end elevation respectively of the engine as exhibited at the Paris Exposition of 1878; and Fig. 1360 is a section of the cylinder and valve, on a somewhat larger scale. From the latter it will be seen that the cylinder, open at the front end,

1357.

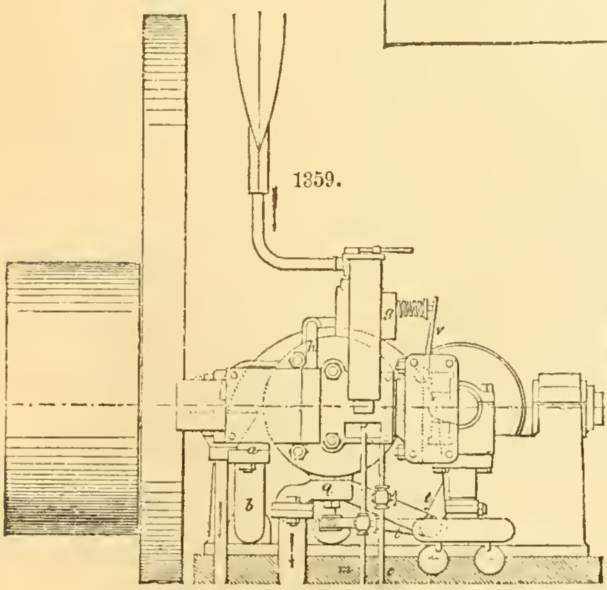


is fitted at back with a cover *A* carrying certain ports, and having a face against which a slide-valve *B* can work, this valve being kept in place by a separate cover *C* held against it by the two spiral springs shown in Figs. 1357 and 1358. The action of the valve is as follows: When the piston is

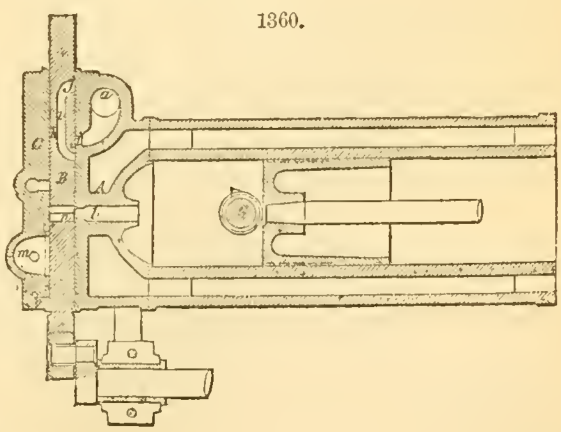
1358.



1359.



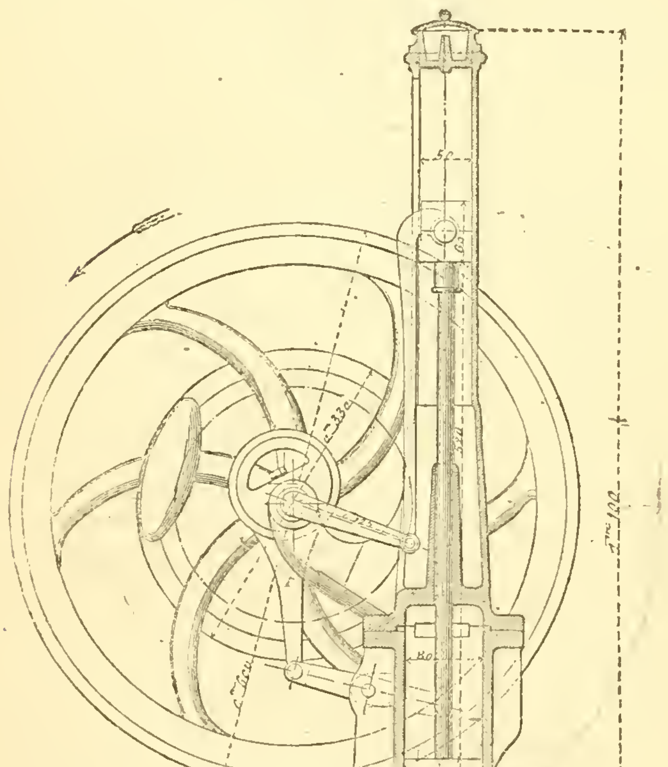
1360.



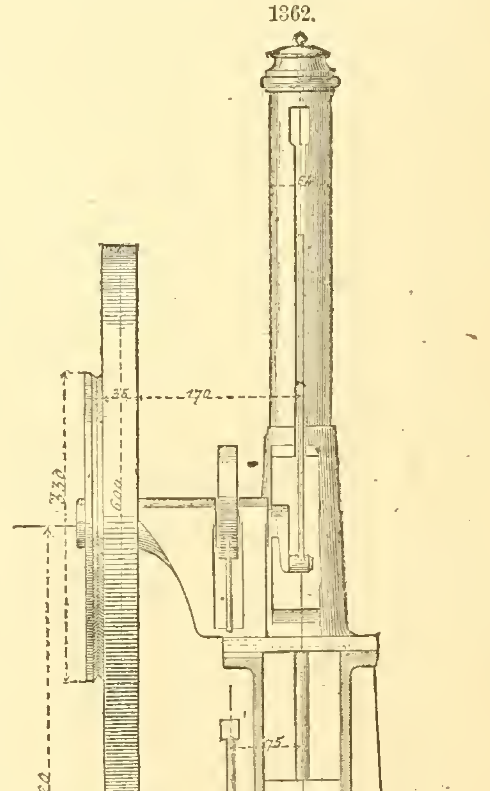
at the back of its stroke ready to draw in the explosive mixture, the valve *B* is in such a position that the port *j i* in it makes communication between the passage *j* and *l* in the cylinder-end *A*. When the piston moves it draws in air through the valve from the opening *a* and the pipe *b*, and at

the same time draws in gas through the small opening $k$ on the back of the valve, which is then just opposite the passage in the valve-cover $c$, which communicates with the pipe $h$ above. The admission opening having been thus made and closed, the piston begins to return, and during its return the valve, moving continuously, keeps the port $l$ closed. Just as the second stroke commences the passage $n$ comes opposite $l$, having just been in communication with $m$ and $o$. In the chamber $m$ a small gas-jet is always burning, fed by the pipe $m$, Fig. 1359, and through $o$ a small stream of gas is allowed to pass. The passage $n$ is thus filled with gas from $o$ ignited from $m$, just as it comes to $l$; this ignites the mixture in the cylinder and starts the stroke, while on the return stroke of the piston the spent gases are discharged through the opening $q$ in the bottom of the cylinder. In order to carry out the function we have described, it is simply necessary that the valve should make only one reciprocation for two strokes of the piston, and for this purpose it is driven by a crank on the end of a lay shaft which revolves with half the velocity of the crank-shaft (the bevel-gear shown in the figures being 2 : 1). This crank and the end of the shaft are seen in Fig. 1360. The same lay shaft serves also to work the governor and two other valves. It carries a cam $r$, which by means of a lever $v$ opens periodically a valve $g$ (closed again by a spring), which regulates the amount of gas admitted through $h$ per stroke. A second cam $s$, by means of a lever $t$ below the cylinder, opens and closes the exhaust-valve $q$. The governor is worked from the lay shaft by the bevel-gearing shown in Figs. 1357 and 1358. In the engines exhibited at Paris it differs somewhat from the form shown in our figures; it is merely a small loaded-ball governor of a neat arrangement. By means of a lever $w$ it controls the position of the cam $r$ upon the shaft, so that, if the speed of the engine exceed a certain limit, the gas-admission valve $g$ is left closed, and the engine runs on until sufficient of its stored-up energy is expended to bring the speed down to its proper level. The cylinder is inclosed in a water-jacket in order to prevent overheating. To insure a circulation of water, it has been found sufficient simply to connect the top and bottom of the jacket with the top and bottom of a filled reservoir. The difference in the densities of the hot and cold water is enough to set up and maintain the requisite circulation. The water enters by the pipe $D$ and returns to the reservoir by $E$, being cooled sufficiently by contact with the air to be used continuously. To avoid shock at exhaust, the

1361.



1362.



hot gases are discharged through a pipe $V$ into a reservoir placed at a little distance, from which they pass into the atmosphere by the pipe $y$ and the nozzle $z$. The lubrication of the piston and valve is effected by the self-acting lubricator $a\,a$, driven from the lay shaft. The engine is stated to consume about 20 cubic feet of ordinary coal-gas per horse-power per hour.

For light industrial uses it would seem that the Bischof engine, represented in Figs. 1361 and 1362, is especially adapted. The machine illustrated, which was exhibited at the Paris Exposition of 1878, is known as a "one-man power" machine (equivalent to $\frac{1}{12.5}$ horse-power). The machine has only two principal castings—a base-plate, with which the vertical cylinder is cast, as well as the valve-chamber, and the cylinder cover and stuffing-box, prolonged above to form a guide for the piston-rod head, and having the bearing-bracket for the shaft cast along with it. The space above the piston communicates freely with the air by the rectangular opening shown. The bottom of the cylinder has a single port communicating with the chamber of a plain piston-valve, the only valve used, which when raised opens communication with the exhaust, and when down (as in position shown) puts the cylinder in connection with the gas- and air-inlet openings. This valve is worked by an ordinary eccentric through the intervention of a rocking lever. The eccentric is placed about 135° in advance of the crank. About a third of the stroke up the cylinder there is a little opening on one side of the latter, opposite which, outside, is the nozzle of a small gas-pipe; and directly below this nozzle there is an ordinary burner connected with the same pipe, the gas at which is kept always lighted. The two burners are protected from draughts by inclosure in a box casing. The upper burner is the real ignition jet; the function of the lower one, which is burning continuously, is simply to relight the other when it is blown out. The crank-shaft lies across the machine, a considerable distance from its axis, the apparent irregularity of action of this arrangement being ingeniously taken advantage of, as will be seen. The action of the machine is as follows: The piston, being at the bottom of its stroke, is at first raised by the energy stored in the fly-wheel and counterweight, and draws into the cylinder the mixture of air and gas through the valve. As soon as the bottom of the piston rises above the opening in the cylinder side above mentioned, the jet outside explodes the mixture, and the explosion drives the piston to the top of its stroke. In the expansion thus brought about, the pressure under the piston falls below that of the atmosphere, so that in its descending course the piston is at first driven downward by the atmosphere acting upon it. This helps to make the machine work more uniformly, although, of course, it is in reality only single-acting. The position of the connecting-rod is so adjusted that it has a very direct pull on the crank just when this is most wanted, during the time when the explosion drives the piston upward. Its oblique position comes only when the piston is descending, and for the most part when the connecting-rod is doing no work, being simply carried down by the fly-wheel. So far, therefore, as oblique pressures are concerned, the skew action of the connecting-rod and its extreme shortness do not do any harm, while the arrangement adopted reduces the space occupied by the engine to very small dimensions. Each of the two India-rubber gas-pipes is carried through a spring closer. This consists simply of an upright bracket, having a thin flat spring carried up beside it, adjustable at the top by a milled finger-nut. The pipe is held between the spring and the standard, and can be closed at will by turning the nut, which gives a very fine adjustment for regulating the quantity of gas passing. An eye is attached to the centre of the spring for the purpose of carrying away a cord from it, so that the workman can adjust the gas supply without leaving any machine at which he is occupied. Two special features claimed for this machine are: first, that it works without grease or other lubricant on either valve or piston; and second, that it requires no water for cooling. The heat from the cylinder is got rid of sufficiently quickly by radiation, a number of radial ribs being cast from the cylinder to increase its surface for this purpose. The consumption of gas is about 11.6 cubic feet per hour, or about 145 cubic feet per horse-power per hour.*

The Simon engine, while based on the same principles as the Otto engine, is differently constructed. The compression of the mixture is done in a separate cylinder, and the air and gas, after compression, are led to the motor-cylinder. There the mixture at once meets an ignited jet, which inflames it. It does not enter the cylinder, however, all at once, but in small quantities, which are successively ignited, thus determining true gradual expansion. The heat developed is small, and a very limited quantity of water prevents overheating of the cylinder. The movement is regular and even. According to M. Simon, the expenditure of gas is 17.6 cubic feet per horse-power per hour.

In the Lenoir engine, the mixture of gas and air is admitted into the cylinder at atmospheric pressure, which is maintained until the piston has made half its stroke; the admission of a spark determines the explosion.

In the Ravel engine, the explosive force of the mixture is employed to move the piston, which is inclosed wholly in the cylinder, motion being taken from the cylinder and not from the piston. When the gas is exploded by a flame, the piston is driven to the opposite end of the cylinder. Its weight at the extremity then causes the latter to overbalance, and hence the cylinder rotates on its trunnions.

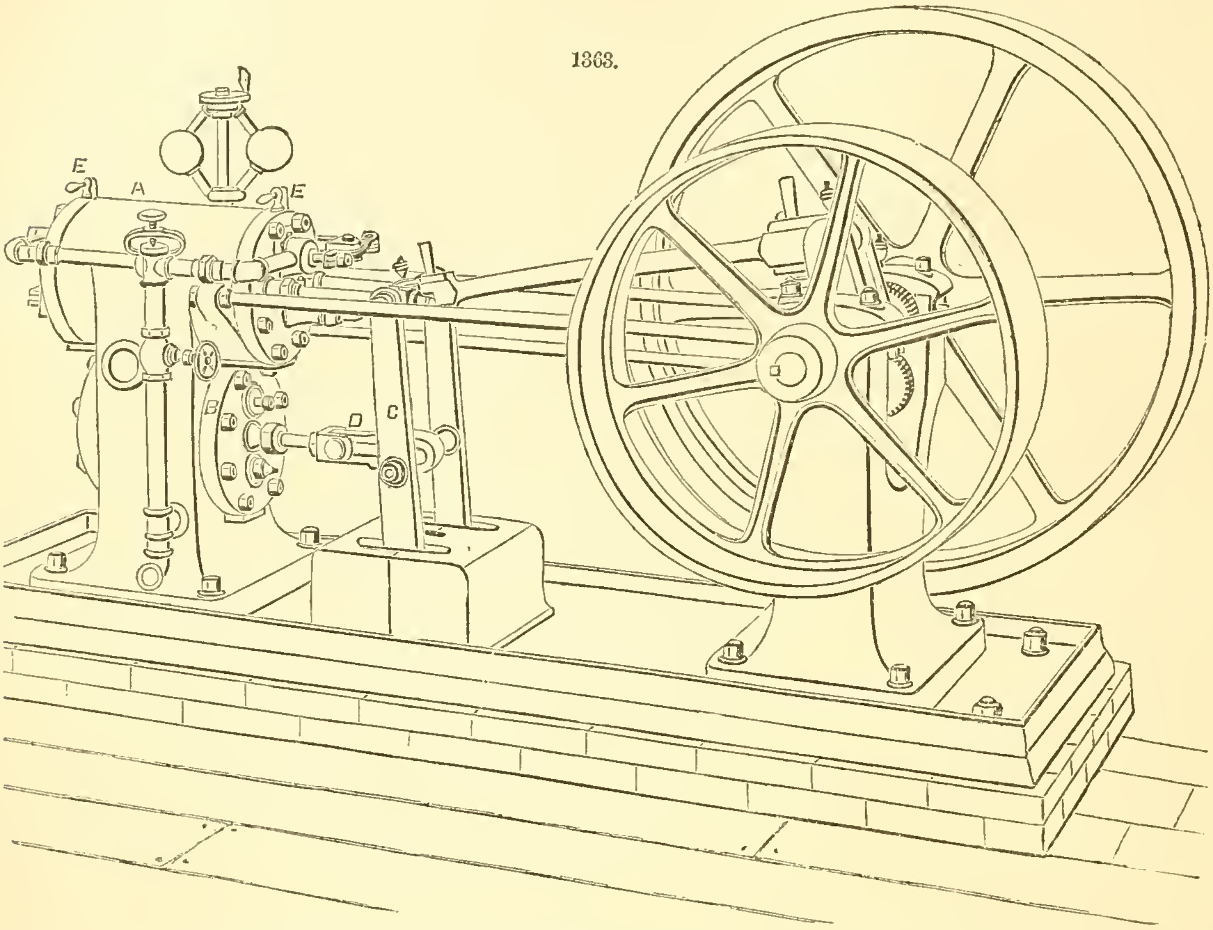
The vapor engine designed by G. H. Brayton, and illustrated in Figs. 1363 and 1364, in its earlier form was driven by a mixture of illuminating gas and air, in such proportions that a rapid combustion rather than an explosion resulted when the mixture was brought into contact with a lighted gas-jet. In the engine as constructed at present, the vapor from petroleum mixed with air is used. Fig. 1363 is a general view of the engine, and Fig. 1364 is a section of enough of the working parts to illustrate the action. The following description is from *Engineering* for Feb. 16, 1877:

"In Fig. 1363, $A$ is the working cylinder and $B$ the air-pump. A parallel motion for the piston is provided as follows: $C$ is a lever, the lower end of which is a vertical foot, the circle being struck off the centre of the cross-head to which the arm or lever $C$ is pivoted by a journal. The radial foot of $C$ rests upon a pathway parallel with the bore of the cylinder; hence, as the piston cross-head moves along, the radial foot rolls along the pathway. In Fig. 1364, $A$ represents the combustion-chamber, in which the vapor forms continuously, and $B$ the safety device, which is composed of perforated plates with diaphragms of wire gauze between them, through which, on the principle of the Davy lamp, it is impossible for the flame in the chamber to pass. At $C$ is shown an annular groove

* *Engineering*, xxvi., 333.

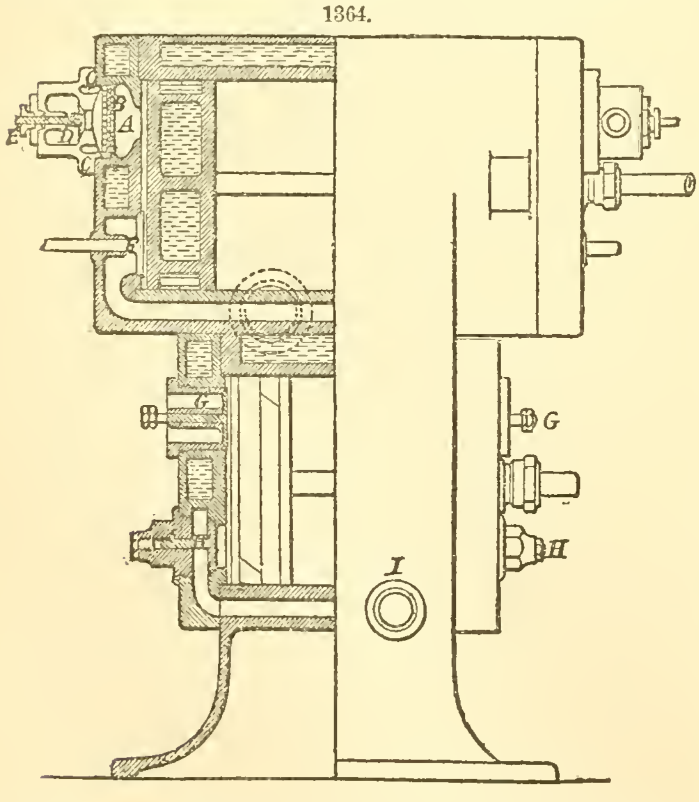
packed with felt or sponge, into which the petroleum is fed by a small pump. A small jet of air is also introduced into the fibrous material while it is moistened with the petroleum. As the supply of this jet is constant and under considerable pressure, the result is that the petroleum is forced out

1363.




in the form of spray, which is spread over and absorbed by the meshes of wire gauze. The air under pressure delivered by the air-pump passes in volume from the air-chest *D* through the valve *E*, to fill the cylinder. This volume of air (which is under a pressure varying from 30 lbs. to 75 lbs., according as regulated to suit the duty) in passing through the gauze takes up the spray, mechanically evaporating it as it enters the combustion-chamber. The small air-jet is carbonized to a degree rendering its combustion continuous, as previously indicated. To start the engine, the two plugs *E E*, in Fig. 1363, are taken out of the cylinder, and the small pump is worked by hand through the means of the small hand-wheel shown on the top of the governor; the small air-jet is then let in, and a match is applied to the holes from which the plugs were removed. So soon as the combustion takes place, the plugs are reinserted and the supply of air from the reservoir is turned on, whereupon the engine starts instantly. In Fig. 1364, the dotted lines indicate the water passages by which the cylinders and the working piston are kept as cool as may be desired. The motive power then is produced by the whole products of combustion acting upon the piston. The point of cut-off is regulated by the point at which the valve *E* closes. The exhaust takes place through the valve *F*, which is operated by a positive motion, all the valves being worked from one shaft, and the valve *E* being attached to the governor. The inlet-valves to the pump are shown at *G G*; they are connected together by a rod and work automatically. The air-

1364.



pump discharge valves are shown at $H H$, the hole $I$ being for the purpose of attaching a pipe to an independent reservoir, which is required in some cases. Suppose, for example, an engine is sometimes required to perform for a short period a duty much above its average allotted duty; then, when running under the lesser load, air may be compressed and stored in a suitable receptacle; and when the load is excessive, the air-pump may be relieved or partially relieved of duty, and the air stored may be used. To provide sufficient air-pressure to start the engine in the morning, the frame of the engine contains an air-reservoir, the hole $I$ being plugged up unless the extra air-reservoir referred to is employed.

"The small pump which supplies the petroleum deserves notice. The plunger is but about thirteen-sixteenths of an inch in diameter, its stroke being adjustable from one-sixteenth to one-half of an inch, by which means the supply of oil to suit any desired speed and power of engine is regulated; and with a given length of stroke the same number of drops of oil will be pumped, whether the engine is running at its slowest, that is, 80 revolutions per minute, or its calculated 180 revolutions per minute."

For works for reference, see ENGINES, HEAT. R. H. B.

ENGINES, HEAT. See ENGINES, AËRO-STEAM AND BINARY VAPOR—AIR—GAS AND VAPOR—SOLAR—STEAM, HOISTING—STEAM, MARINE—STEAM, PORTABLE AND SEMI-PORTABLE—STEAM, PROPORTIONS OF—STEAM, STATIONARY, RECIPROCATING—STEAM, STATIONARY, ROTARY—STEAM, UNUSUAL FORMS OF.

*Theory of Heat-Engines.*—According to the dynamical theory of heat, a given amount of work is always convertible into an equivalent amount of heat; or, to speak more definitely, one unit of heat is the equivalent of 772 foot-pounds of work. (See DYNAMICS.) By a unit of heat is meant the amount of heat required to raise the temperature of a pound of distilled water from 39° to 40° F.; and work of any kind can always be expressed as a given number of pounds raised so many feet high. For instance, if a wagon is drawn along a road for a mile with a constant force of 50 lbs., the work done is equivalent to raising 50 lbs. through a height of 5,280 feet, or $50 \times 5{,}280 = 264{,}000$ foot-pounds; and if a perfect engine had been employed to do the work, it would have required $264{,}000 \div 772 = 342$ units of heat.

The steam, air, and vapor engines in common use offer familiar examples of the conversion of heat into work. Coal is burned in a furnace, for instance, imparting heat to a fluid, such as water or air; and then a portion of the heat so imparted may be utilized in performing the work of moving the engine-piston and overcoming resistance. If all the heat derived from the combustion of the coal was imparted to the working fluid, and then by its expansion converted into work, this would represent perfect action, which is of course far from being realized in practice. Thus, suppose that the heat received by the fluid from a pound of coal is 15,000 units, then the work done per hour for each pound of coal burned is $772 \times 15{,}000 = 11{,}580{,}000$ foot-pounds, or nearly 6 horse-power; showing that the best modern engines only utilize a small fraction of the heat developed by the combustion of the fuel. The reasons for this waste will be given hereafter.

It will be evident from the above that any form of engine which is made to work through the agency of heat is properly designated as a heat-engine; and that this general term covers the various classes which are described under their several headings, viz.: air-engines, steam-engines, gas-engines, vapor-engines, and solar engines—the distinctive names referring either to the kind of working fluid employed, or the means of imparting heat.

It may be well, at the outset, to call attention to the fact, which is often overlooked, that the effect of a heat-engine depends, not upon the working fluid that is employed, but upon the extremes of temperature in the working cylinder. Suppose, for example, that the fluid is admitted into the working cylinder at an absolute temperature $T$, and that, after moving the piston by its expansion, its absolute temperature is reduced to $t$, when it is expelled from the cylinder; the efficiency of the engine is represented by the fraction $\frac{T-t}{T}$. (The absolute temperature is the temperature measured from the absolute zero, which is fixed by theory at $-461.2°$ F., so that the absolute temperature = temperature on Fahrenheit's scale + 461.2°.) Thus, suppose that in a condensing engine the steam is admitted at a temperature of 330°, and that at the end of its expansion in the cylinder the temperature is 200°; the effect would be only $\frac{(330+461.2)-(200+461.2)}{330+461.2} \times 100 = 16.4$ per cent. of the total efficiency of the fluid. Or supposing the total effect of the heat imparted to the fluid was 6 horse-power, the useful effect would be only 0.984 horse-power, and 5.016 horse-power are lost.

From the above principle it appears that the means of increasing the efficiency of an engine consists in increasing the difference of temperatures between which it works, either raising the higher temperature, lowering the other, or both. It appears further, from the principle, that it is a matter of indifference what fluid is used in the engine, provided the initial and final temperatures are fixed. It may be easier, however, to maintain a given difference of temperature with one fluid than another, so that under certain conditions special advantages will result from the use of a particular fluid.

*Horse-Power.*—As already remarked, resistance overcome in any case in which motion ensues, if it can be measured, is convertible into the amount of work that is done in raising a weight equal to the given resistance through a height equal to the space over which this resistance is moved. A common measure for a unit of work is the amount required to raise one pound through a vertical distance of one foot. To illustrate, suppose that a cut is being taken from a 6-inch shaft in a lathe, and that the resistance to the motion of the cutting tool is 200 lbs.; then in each revolution of the shaft the tool takes a cut 1.5708 foot in length, so that the work done per revolution is the same as would be expended in raising a weight of 200 lbs. through a vertical distance of 1.5708 foot, or it is 314.16 foot-pounds.

Power is the measure of the amount of work done in a given time; and the conventional unit of

power, known as a *horse-power*, is equivalent to 550 foot-pounds of work per second, 33,000 per minute, or 1,980,000 per hour. If, in the preceding example, the shaft makes 20 revolutions a minute, the work done per minute is $314.16 \times 20 = 6,283.2$ foot-pounds; so that the power required to drive the tool is $6,283.2 \div 33,000 = 0.19$ horse-power. The term horse-power, when used in connection with an engine, is variously applied. The most common distinctions are as follows: 1. Gross or indicated horse-power. 2. Net or effective horse-power. 3. Total horse-power. 4. Nominal horse-power.

The *gross* or *indicated* power of an engine is calculated from the mean effective pressure in the cylinder, usually determined, in the case of heat-engines, by an indicator. If, for example, it is found that the mean pressure is 2,500 lbs., moving the piston at the rate of 400 feet a minute, the gross horse-power is $\frac{2500 \times 400}{33000} = 30.3$.

The *net* or *effective* horse-power is calculated from the pressure exerted by the engine in useful effect, which can be determined by a dynamometer. Suppose the useful pressure in the preceding example is 2,200 lbs., then the net horse-power is $\frac{2200 \times 400}{33000} = 26.7$.

The *total* horse-power of an engine is calculated from the total pressure in a cylinder above a vacuum, which can be found from an indicator diagram. If, for example, the mean total pressure is 4,200 lbs., and the piston speed 400 feet per minute, the total horse-power is $\frac{4200 \times 400}{33000} = 50.9$. Total horse-power is sometimes used in comparisons of the results of experiments. Another application is illustrated on page 624.

The *nominal* horse-power of an engine can scarcely be said to have any definite meaning, since there are a number of different rules by which it may be computed. Thus, there is the Admiralty rule for marine engines, Mr. Bourne's rules for condensing and non-condensing engines, and James Watt's rule, all of which are in common use; and in addition numerous engine-builders have what may be called proprietary rules. For instance, one builder, A, may say, "I will make a steam-engine with a cylinder 10 inches in diameter, and a stroke of 15 inches, and I will call it 8 horse-power, nominal." Another builder, B, who makes an engine of the same size, and desires to impress purchasers with the idea that he gives them more for the same price than his competitors do, may say, "I will rate my engine at 16 horse-power, nominal." The above illustration represents quite accurately the capricious use that is made of the term "nominal horse-power;" and the intelligent engine-buyer may very properly inquire of the builder, "How much will you charge me for an engine guaranteed to develop so much horse-power, actual?"

*Works for Reference.*—The literature of the steam-engine is so extensive that it is here impossible to give a full list. Copious references to transactions and periodical literature have been introduced throughout the various articles in their proper connections, so that the list that follows is confined to general treatises and text-books. Works on appliances related to the steam-engine, such as indicators, etc., will be found quoted in the articles treating thereon.

*Historical:* "History of the Steam-Engine," Stuart, London, 1824; "Treatise on the Steam-Engine," Farey, London, 1827; "Anecdotes of the Steam-Engine," Stuart, London, 1829; "The Steam-Engine, its Invention," etc., Tredgold, London, 1838; "Mechanical Inventions of James Watt," Muirhead, London, 1854; "Life of James Watt," Muirhead, London, 1859; "Life, Times, and Scientific Labors of the Second Marquis of Worcester," Dircks, London, 1865; "Lives of Boulton and Watt," Smiles, London, 1865; "Life of Richard Trevithick," Trevithick, London, 1872; "A History of the Growth of the Steam-Engine," Thurston, New York, 1878.

*Theoretical* (chiefly): "Théorie des Machines à Vapeur," De Pambour, 2d ed., Paris, 1844; "Relation des Expériments pour déterminer les principales Lois, etc., des Machines à Vapeur," Regnault, Paris, 1847; "Leçons de Mécanique Pratique," Morin, Paris, 1846 (3d part); "Traité théorique et pratique des Moteurs," Courtois, Paris, 1846; "Analytical Principles, etc., of the Expansive Steam-Engine," Hodge, London, 1849; "Theorie des Dampfmaschinen," Schmidt, Freiberg, 1861; "Théorie mécanique de la Chaleur," Hirn, 2d ed., Paris, 1865; "Théorie mécanique de la Chaleur, avec ses Applications aux Machines," Zeuner, Paris, 1869 ("Grundzüge der Mechanischen Wärmetheorie," Leipsic, 1866); "Heat and Steam," Williams, Philadelphia, 1871; "Heat as a Source of Power," Trowbridge, New York, 1874; "The Mechanical Theory of Heat and its Application to Steam-Engines," McCulloch, New York, 1876; "Heat as a Mode of Motion," Tyndall, New York, 1876; "Traité de Mécanique Général," Resal, Paris, 1876; "The Steam-Engine Considered as a Heat-Engine," Cotterill, New York, 1878.

*Elementary Treatises* (general): "The Steam-Engine familiarly Explained," Renwick, Philadelphia, 1848; "Steam and Steam-Engines," Clarke, London, 1875; "Catechism of the Steam-Engine," "Hand-book of the Steam-Engine," Bourne, London and New York, 1876; "The Theory and Action of the Steam-Engine," Northcott, London, 1877; "Wrinkles and Recipes," Benjamin, New York, 1878.

*On Marine Engines:* "Catéchisme du Marin et du Mécanicien à Vapeur," Paris, 1850; "Engineering Precedents," Isherwood, New York, 1858; "A Study of Steam and Marine Engines" (elementary), Saxby, London, 1862; "Experimental Researches in Steam-Engineering," Isherwood, Philadelphia, 1863; "The Cadet Engineer" (elementary), Long and Buel, Philadelphia, 1865; "Marine Steam-Engine," Main and Brown, Philadelphia, 1865; "Modern Marine Engineering," Burgh, London, 1867; "Lessons and Practical Notes on Steam," King, New York, 1867.

*General Treatises:* "Sammlung von Zeichnungen einiger ausgeführten Dampfkessel und Dampfmaschinen," Rottebohm, Berlin, 1841; "Die Hochdruckdampfmaschine," Alban, Rostock, 1843; "Mémoire sur les Machines à Vapeur," Reech, Paris, 1844; "Traité des Machines à Vapeur," Bataille and Jullien, Paris, 1849; "Traité élémentaire et pratique des Machines à Vapeur," Gaudry,

Paris, 1856; "Anleitung für Anlage und Wartung der stationären Dampfkessel," Marin, Brünn, 1859; "American Engineering, embracing various Branches of Mechanics," Weissenborn, New York, 1861; "Practical Rules for Proportions of Modern Engines and Boilers," Burgh, Philadelphia, 1865; "Treatise on the Steam-Engine," Bourne, 7th ed., 1866; "A Manual of Steam-Engines and other Prime Movers," Rankine, 3d ed., London, 1866; "Der Führer des Machinisten," Scholl, Braunschweig, 6th ed., 1864; "Die Dampfmaschinénberechnung Mittels, praktischer Tabellen und Regeln," Hrabák, Prague, 1869; "Manuel de l'Ingénieur, 7e et 8e Fascicules," De Bauve, Paris, 1873; "Compound Steam-Engines," Turnbull, New York, 1874; "Compound Engines," Mallet, New York, 1874; "A Practical Treatise on the Steam-Engine," Rigg, London and New York, 1878; "The Mechanics of Engineering," Weisbach, translated by Du Bois, Vol. II., 1878; supplement to same, 1879.

*Treatises on Special Subjects:* "The Slide-Valve," Burgh, London, 1868; "Link Motion and Expansion Gear," Burgh, London, 1872; "Recent Improvements in the Steam-Engine," Bourne, London, 1874; "Link and Valve Motion," Auchincloss, 6th ed., New York, 1875; "Designing Valve-Gearing," Welch, New York, 1875; "The Relative Proportions of the Steam-Engine," Marks, New York, 1878. R. H. B. (in part).

ENGINES, PROPORTIONS OF PARTS OF. The rules that follow, showing the manner of calculating the proper sizes for the principal parts of engines, are mainly derived from Van Buren's treatise on "The Strength of Iron Parts of Steam Machinery," a work which should be in the hands of every designer. The formula for the length of crank-pins is from an article on the subject by Theron Skeel, published in the *Iron Age* for Aug. 21, 1873.

*Notation.*—D = diameter of cylinder in inches; S = length of stroke in inches; $l$ = length of rod or pin in inches; $d$ = diameter of rod or pin in inches; $t$ = thickness of cylinder in inches; $p$ = boiler pressure by gauge + 15, in pounds per square inch; I = indicated horse-power.

1. *Thickness of cylinder.*

$$t = 0.0001 \times D \times p + 0.15 \times \sqrt{D}$$

$$p = \frac{10{,}000 \times t}{D} - \frac{1{,}500}{\sqrt{D}}$$

2. *Diameter of piston- and connecting-rods.*

$$d = \text{constant} \times D \times \sqrt{p}.$$

$$p = \frac{d^2}{(\text{constant})^2 \times D^2}$$

3. *Constants for Rule* 2.—The constants depend upon the length of the rod, so that the rule must be solved by approximation. A table is appended, giving the constants for different ratios of length to diameter.

*Constants for Diameter of Piston-rods and Connecting-rods.*

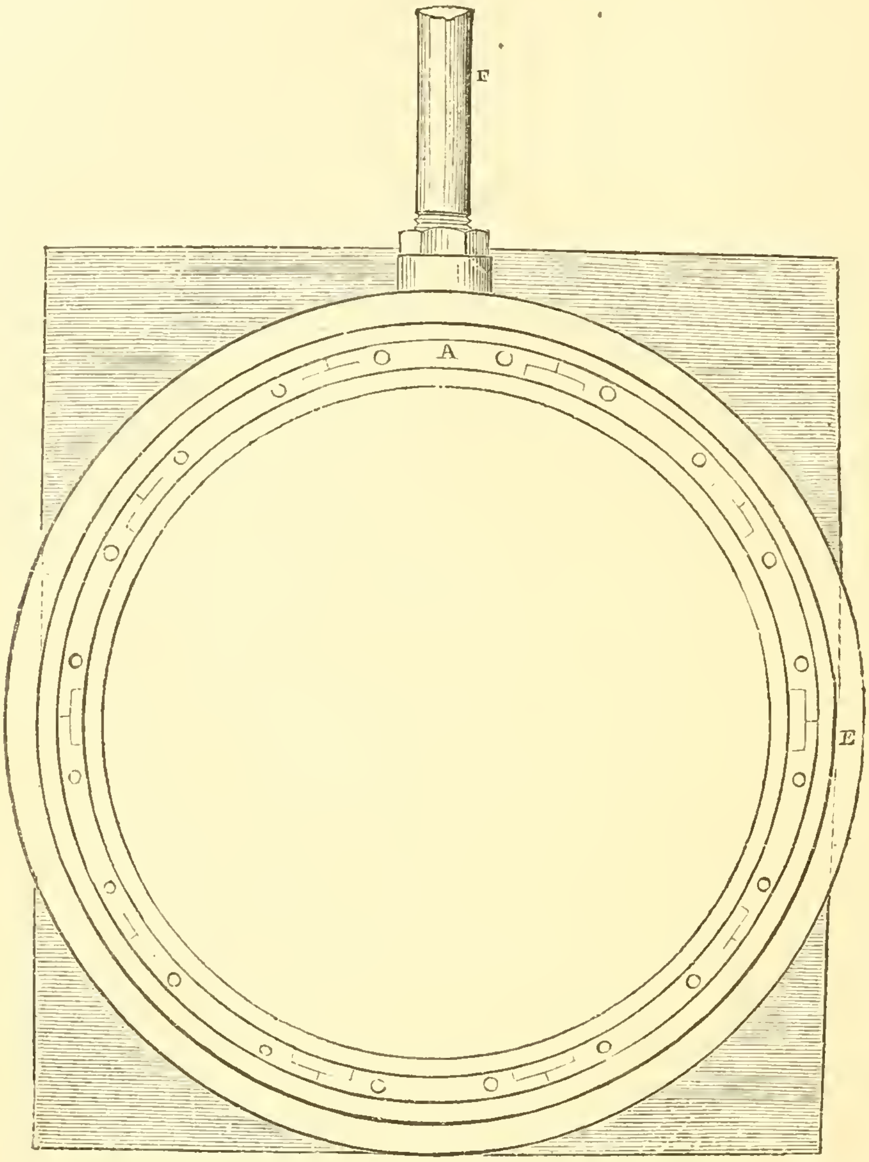
| RATIO OF LENGTH TO DIAMETER. | PISTON-RODS. | | CONNECTING-RODS. | | RATIO OF LENGTH TO DIAMETER. | PISTON-RODS. | | CONNECTING-RODS. | |
|---|---|---|---|---|---|---|---|---|---|
| | Wrought Iron. | Steel. | Wrought Iron. | Steel. | | Wrought Iron. | Steel. | Wrought Iron. | Steel. |
| 8 | .01531 | .01250 | .01553 | .01268 | 25 | .01837 | .01500 | .02017 | .01647 |
| 9 | .01541 | .01258 | .01569 | .01281 | 26 | .01862 | .01521 | .02054 | .01677 |
| 10 | .01552 | .01268 | .01587 | .01296 | 27 | .01889 | .01542 | .02092 | .01708 |
| 11 | .01565 | .01278 | .01606 | .01311 | 28 | .01915 | .01564 | .02131 | .01740 |
| 12 | .01578 | .01289 | .01627 | .01329 | 29 | .01942 | .01586 | .02170 | .01772 |
| 13 | .01593 | .01301 | .01650 | .01347 | 30 | .01970 | .01609 | .02209 | .01804 |
| 14 | .01608 | .01313 | .01674 | .01367 | 31 | .01999 | .01632 | .02250 | .01837 |
| 15 | .01625 | .01327 | .01699 | .01387 | 32 | .02027 | .01655 | .02291 | .01870 |
| 16 | .01642 | .01341 | .01726 | .01409 | 33 | .02057 | .01679 | .02332 | .01904 |
| 17 | .01661 | .01356 | .01754 | .01432 | 34 | .02087 | .01704 | .02374 | .01939 |
| 18 | .01680 | .01372 | .01783 | .01456 | 35 | .02117 | .01728 | .02417 | .01974 |
| 19 | .01700 | .01388 | .01813 | .01481 | 36 | .02148 | .01753 | .02460 | .02009 |
| 20 | .01721 | .01405 | .01845 | .01506 | 37 | .02179 | .01779 | .02504 | .02044 |
| 21 | .01743· | .01423 | .01878 | .01533 | 38 | .02210 | .01805 | .02547 | .02080 |
| 22 | .01765 | .01441 | .01911 | .01560 | 39 | .02242 | .01831 | .02592 | .02116 |
| 23 | .01788 | .01460 | .01946 | .01589 | 40 | .02274 | .01857 | .02636 | .02153 |
| 24 | .01812 | .01480 | .01981 | .01618 | .. | ...... | ...... | ...... | ...... |

Rule 2 can be applied for finding the dimensions of pump-rods and valve-stems, substituting in the case of pumps the pressure in pounds per square inch on the pump-bucket for the steam-pressure. For unbalanced valves, the pressure can be taken as three-tenths of the weight of the valve in the steam-pressure. In giving this value for the coefficient of friction of the valve on its seat, it is proper to remark that there is great difference of opinion among engineers in relation to this subject, and extended discussions will be found in the files of technical papers. Some interesting notes on the friction of slide-valves, with experiments by Mr. Thomas Adams, are contained in the "Transactions of the Society of Engineers" for 1866. The loss of power occasioned by this friction has been considered so serious by many engineers, that numerous forms of balanced valves, in which the pressure is taken off the valve by a packing ring at the back, or by connecting the back of the valve with the condenser, have been devised. The majority of these valves have been unsuccessful, on account of various imperfections of detail. A valve composed of two solid pistons connected by a stem has, however, been largely introduced, and with the Davis improvement, which consists in jacketing the steam-chest, has generally given very satisfactory results. The construction of the Davis valve is shown in Fig. 1433.

A valve balanced by a ring on the back is represented in Figs. 1365 and 1366. The ring is divided into segments which are pressed against the inner side of the valve-chest back by spiral springs and steam pressure. *a a a* is a brass ring divided into segments, as shown in the plan, the object being to allow the ring to accommodate itself to any slight curve that may be caused by the pressure of steam on the valve-box back or cover. *b b b b* is a space containing about three layers of well-plaited square gasket. *c c c c* is a brass ring in one piece fitted loosely into the groove, having on one side

of it a number of small steel pegs, *d d d d*, on which are placed spiral springs. These springs force the ring, and by it the hemp packing is pressed hard against the brass segments, causing them to slide steam-tight against the valve-box cover, the pressure being further regulated by a communica-

1365.




BACK VIEW.

tion made between the space in which the spiral springs work and the steam in the valve-box. A communication is made between the condenser and the space within the brass ring *a a a* in the valve-box cover, and the condenser regulated by a cock, so that when the engineer is handling the engine he can cause a vacuum at the back of the slides. *E E E* is a wrought-iron hoop bound to fit the turned part of the valve, which slides freely in it, uninfluenced by the valve-rod *F F*.

4. *Length of crank-pin.*

$$l = \frac{0.714 \times I}{S}$$

5. *Diameter of crank-pin.*

*a.* Single engine:

$$d = 0.084 \times (D^2 \times p \times l)^{\frac{1}{3}}$$

$$p = \frac{1687.5 \times d^3}{D^2 \times l}$$

*b.* Double engine:

$$d = 0.09925 \times (D^2 \times p \times l)^{\frac{1}{3}}$$

$$p = \frac{1022.75 \times d^3}{D^2 \times l}$$

*c.* Triple engine:

$$d = 0.1159 \times (D^2 \times p \times l)$$

$$p = \frac{642.8 \times d^3}{D^2 \times l}$$

6. *Diameter of shaft.*

*a.* Single engine:

$$d = 0.0684 \times (D^2 \times S \times p)^{\frac{1}{3}}$$

$$p = \frac{3125 \times d^3}{D^2 \times S}$$

*b.* Double engine:

$$d = 0.0768 \times (D^2 \times S \times p)^{\frac{1}{3}}$$

$$p = \frac{2208 \times d^3}{D^2 \times S}$$

*c.* Triple engine:

$$d = 0.0862 \times (D^2 \times S \times p)^{\frac{1}{3}}$$

$$p = \frac{1561 \times d^3}{D^2 \times S}$$

In the case of shafts and crank-pins for double and triple engines, the rules give proportions for the parts that are most strained; so that, if it is desired, each pin and journal can be of a different size, according to the amount of strain.

7. *Thickness of cast-iron steam-pipe.*

$$t = 0.03 \times \sqrt{D \times p}.$$

$$p = \frac{1111 \times t^2}{D}.$$

8. *Proportions of crank.*

*a.* Keys. A single key should have a breadth of 0.4 of the diameter of the shaft or pin if of wrought-iron, and 0.8 of the diameter if of steel. Where two or more keys are used, the above breadth can be divided among the whole number.

*b.* Diameter of hub. For a crank of a rectangular section, such as is commonly employed, the diameter of the hub should be 1.7 time the diameter of the shaft.

*c.* Diameter of eye. Where the pin is secured by keys, the diameter of the eye should be 1.6 time the diameter of the crank-pin.

*d.* Proportion of web of crank. Either dimension, the breadth parallel with the shaft, or the depth, may be assumed, and the other can be found as follows: If the depth is assumed at any point of the web, the breadth at that point

$$= 1.64 \times \frac{(\text{diameter of shaft})^3 \times \text{distance from centre of crank-pin to given point}}{(\text{depth})^2 \times \text{radius of crank}}$$

If the breadth is assumed, the depth

$$= 1.28 \times \left[\frac{(\text{diameter of shaft})^3 \times \text{distance from centre of crank-pin to given point}}{\text{breadth} \times \text{radius of crank}}\right]^{\frac{1}{2}}$$

(All dimensions in inches.)

9. *Straps and bolts exposed to tensile strain.*

The cross-section of a strap in square inches should be 0.000126 of the total strain in pounds to which it is exposed. The strap for a connecting-rod should have a cross-section equivalent to that of the neck of the rod. In computing the effective section of a strap, the sectional area of the holes for keys and bolts must, of course, be deducted.

The proper diameter in inches for a bolt exposed to a given strain in pounds is 0.0132 time the square root of the strain. If the strain is equally distributed among several bolts, the diameter of each is equal to the diameter of a single bolt suitable to resist the strain, as determined above, divided by the square root of the number of bolts.

10. *Gibs and keys exposed to shearing strain.*

The area in square inches required to resist a given strain in pounds should be 0.00016 of the strain.

A few examples illustrating the application of the rules are added:

1. What is the proper thickness for a cylinder 6 inches in diameter, the boiler pressure being 105 lbs. per square inch?

$d = 0.0001 \times 6 \times (105 + 15) + 0.15 \times \sqrt{6} = 0.439$, or about seven sixteenths of an inch.

2. Find the diameter for a steel piston-rod suitable for a cylinder whose diameter is 60 inches, the boiler pressure being 25 lbs. per square inch, and the length of the rod 40 inches.

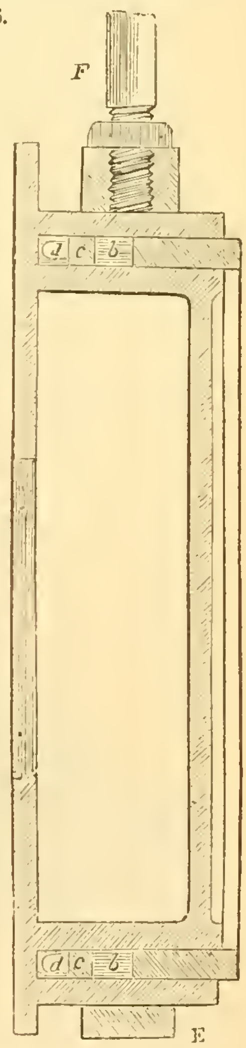
$40 \times \sqrt{25+15} = 252$. Assume the proper diameter to be 4 inches, then the ratio of length to diameter is 10, and, from the table on page 639, the proper diameter for this ratio is $252 \times .0127 = 3.2$, so that the assumed diameter is too large. By one or two similar trials in the table, it is found that the proper diameter corresponds to a ratio of about 12, making its value $252 \times 0.0129 = 3.25$ inches.

3. What is the proper working pressure for a wrought-iron connecting-rod $3\frac{1}{2}$ inches in diameter, its length being 70 inches, and the diameter of the cylinder 24 inches?

The ratio of length to diameter being 20, the working pressure is $\frac{3.5^2}{0.0185^2 \times 24^2} = 62$; or the boiler pressure is $62 - 15 = 47$ lbs. per square inch.

1366.


TRANSVERSE SECTION.




PERPENDICULAR SECTION.

4. An engine with a stroke of 30 inches develops 250 indicated horse-power. The proper length for the crank-pin is: $l = \frac{250 \times 0.714}{30} = 5.95$; say 6 inches.

5. A certain engine has a cylinder 24 inches in diameter, and a crank-pin 5 inches long. The boiler pressure is 65 lbs. Hence the proper diameter for the crank-pin is: $d = 0.084 \times (576 \times 80 \times 5)^{\frac{1}{3}} = 5.15$; about $5\frac{1}{8}$ inches.

6. A cast-iron pipe is 6 inches in diameter, and the boiler pressure is 50 lbs. per square inch. The thickness, $t = 0.03 \times \sqrt{6 \times 65} = 0.57$; about nine-sixteenths of an inch. R. H. B.

ENGINES, SOLAR. The total steam-power of the world has been roughly estimated by statisticians at between 15,000,000 and 16,000,000 horse-power. From the data obtained by Herschel and Pouillet, Capt. Ericsson concludes that if all the heat of the sun falling on a square mile of the earth's surface could be utilized in the generation of steam, it would furnish a supply for engines of about 13,000,000 horse-power. Many investigators, desirous of utilizing at least a portion of the immense supply of power so bounteously placed by nature at their disposal, have turned their attention to the practical means of realizing their ideas. The most prominent experimenters of modern times are Mouchot and Ericsson, who have each arrived at substantially the same practical result. An interesting account of their investigations was published by L. Simonin in the *Revue des Deux Mondes* for 1876, and a translation of his paper may be found in the *Iron Age* for Sept. 14 and 21, 1876. Says M. Simonin:

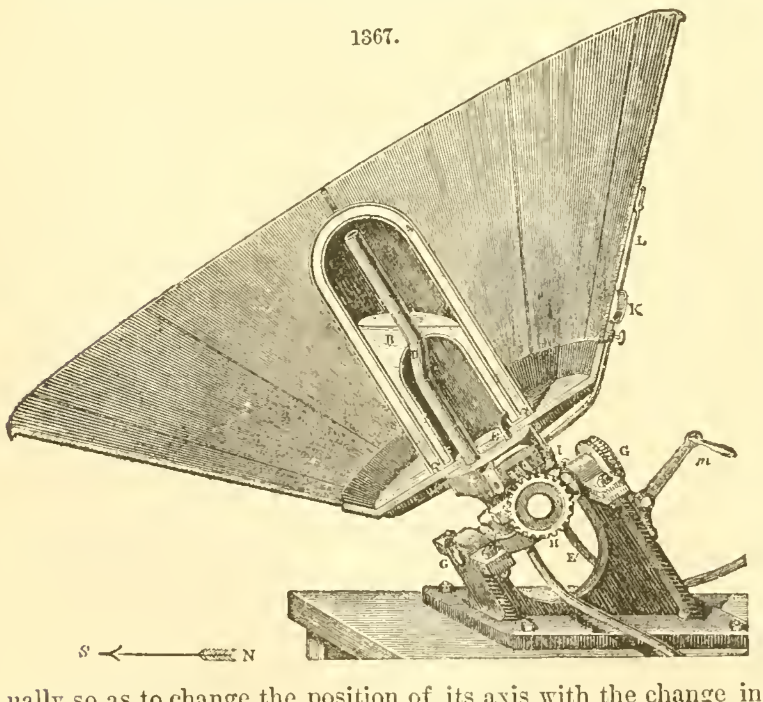
"What is coal? Fossil carbon. And was not this carbon fixed in plants by the sun's heat, of which it is the equivalent? Under the action of solar radiation the carbonic acid in the atmosphere is decomposed on contact with plants; the carbon is fixed in the plant, and the oxygen goes back into the air to serve for the respiration of animals. Hence, no sun, no vegetation; no vegetation, no carbon, no coal. Coal in burning gives up the solar heat which was stored up in it, and therefore it was that, on seeing a locomotive engine move, Stephenson said: 'It is not the coal that drives this engine, it is the sun's heat stored up in the coal thousands of ages ago; locomotives are but the horses of the sun.' We might make a like comparison with respect to wine and the alcohol it contains; and the Bordelais use no mere figure of speech when they speak of their admirable Sauterne wine as being 'bottled sunshine.'

"When water rises in the shape of vapor, what is it that causes it to ascend? The heat of the sun. If it comes down as rain, forming torrents and brooks which feed our mill-races and drive our mills, what is it that turns the wheel? The sun, for it was the sun that in the first place raised the water. When the wind blows upon the sails of a windmill, or upon the sails of a ship, what is it that drives the mill or propels the ship? The sun, for wind is simply an atmospheric current produced by the heating of a stratum of air, which being dilated by the sun tends to an equilibrium with strata of the same density, and hence rises, while a volume of cooler air takes its place. And what are the tides, the propulsive power of which there is some thought of utilizing, whether directly by means of water-wheels, or indirectly by compressing air, and so producing a constant supply of force? They are a portion of the heat of the sun, for the seas are formed by the coming together of all those torrents and rivers which descend into their common reservoir, the ocean. Then, too, the tides are the result of the combined attraction of sun and moon upon the earth. Thus we find that the sun is always and everywhere active.

"It is, therefore, no paradox to regard the sun as the one source of fuel in the future, and as the reservoir of force to which generations to come will at no distant day have recourse. Hence it is that savants and great engineers, as Euclid, Archimedes, Hero, Salomon de Caus, Buffon, Saussure, Belidor, Evans, Herschel, Pouillet, Mouchot, Ericsson, have in every age put to themselves the question how it might be possible to take from the sun a part of its heat for the benefit of this poor globe."

The most successful solar boilers hitherto devised have been those constructed by Mouchot and Ericsson, which are quite similar in their details. An illustration of Mouchot's apparatus, as erected in the courtyard of the library at Tours and at the Paris Exposition, 1878, is shown in Fig. 1367. It will be seen that there is a large mirror, which is silvered, and has the form of a truncated cone, the sides of which are at an angle of 45° to the axis. The boiler, $B$, is made of copper, with double walls, between which the water and steam spaces are comprised, and the exterior of the boiler is blackened. A glass bell, $A$, covers the boiler, to prevent the return of heat imparted to the boiler. The pressure-gauge is shown at $K$, the water-gauge at $L$, and the safety-valve at $I$. The apparatus is so mounted that it revolves 15° an hour around an axis parallel to that of the earth, thus following the apparent daily motion of the sun; and it also inclines gradually so as to change the position of its axis with the change in the sun's declination. The dimensions (*Engineering*, Dec. 31, 1875) are as follows: Diameter of mirror at top, 112.3 inches; at bottom, 39.3 inches; area of mirror, 45 square feet. The two envelopes of the boiler are respectively

1367.



31.5 and 19.7 inches high, and 11 and 8.7 inches in diameter; water space, about 4.4 imperial gallons. The glass bell is 15.8 inches in diameter, 33.5 inches high, and 0.2 inch thick. With this apparatus, under favorable circumstances, 11 lbs. of water have been evaporated per hour, from a temperature of 68° F., and at a pressure of about 75 lbs. per square inch. Such an apparatus does not, of course, completely solve the problem of the successful application of the solar heat to driving an engine, since it does not provide for periods in which the rays of the sun are not available. There have been many plans proposed for storing up the heat received from the sun, to be used at night and on cloudy days. M. Simonin suggests that it will only be necessary to heat good conductors, such as porous stones, in the solar boiler, and then store them away. He says:

"Straw, sawdust, wool, feathers, confined air, are insulating substances which retain heat. We might surround with a double envelope of this kind the reservoir holding the sun-heated stones, and in this way we might have our store of solar heat, as now we have our store of ice. It is one problem whether we have to retain cold or to retain heat. Now, ice keeps very well even when stored in the hold of a vessel; a little sawdust and careful stowage do the whole work. The same means will serve in storing solar heat, and, if need be, shipping it to a distance. We have barely outlined the idea, but certain we are that at the proper time the scientific man will appear who shall discover a practical method of doing this."

G. A. Bergh has proposed to use the solar heat in liquefying carbonic acid, and thus storing up the work of a solar engine for future use. A translation of his remarks, first published in *Poggendorff's Annalen* for 1873, is given in *Van Nostrand's Eclectic Engineering Magazine*, February, 1874. The possible solutions of the problem are by no means exhausted, and the subject offers a vast field for the labors of inventors, and a rich reward to him who is successful.

A paper on "Cooking by Solar Heat," by W. Adams, interesting in this connection, appears in the *Scientific American*, xxxviii., 376. The writer, in Bombay, India, used a combination of flat mirrors, of common sheet glass, silvered, fixed in rectangular frames so as to concentrate the solar rays to a focus at a distance of 20 feet. The focus was about 2 feet in diameter. With 72 pieces of silvered sheet glass, each 15 by 10½ inches, at midday, in the month of May, a focus was formed at a distance of 20 feet, of a temperature above 1088° F. Every kind of wood placed in this focus was instantly ignited, without being, as in Buffon's experiment, previously smeared with tar and shreds of wool. A solid cylinder of water, 18 by 8 inches, contained in a vertical copper vessel provided with a steam-pipe, was then placed in the focus, and it boiled in exactly 20 minutes. The ebullition was exceedingly violent. Another experiment was made with 198 glasses, each 15 by 10½ inches, fixed in 10 rectangular frames. A copper boiler containing 9 gallons of cold water was placed in the focus, and began to boil in exactly 30 minutes. It was allowed to boil for exactly 1 hour, when 3¾ gallons of water were found to have been evaporated. R. H. B.

ENGINES, STEAM, HOISTING. Hoisting or winding engines may be either stationary, portable, or semi-portable. Their construction being such as to adapt them to their specific purpose, they are usually classed as a distinct type of steam-engine, and as such have become the special manufacture of many well-known builders. Their use is the lifting of heavy weights. Their application to passenger-elevators is discussed under ELEVATORS; to raising material from mines, under MINE APPLIANCES. The machines here presented are those which may be employed for a variety of uses.

Fig. 1368 represents a differential hoisting engine manufactured by W. D. Andrews of New York. The hoisting drum has a grooved friction-wheel at each end, one wheel being 30 inches and the other 26 inches in diameter. The pinions upon the engine-shaft engaging with these wheels are respectively 4 and 8 inches in diameter. By means of levers which communicate with eccentrics, one of which is shown in Fig. 1369, either wheel may be brought into or moved out of contact with its pinion. When the large wheel is in contact, the drum has 1 revolution to 7½ revolutions of the engine; with the small wheel engaged, the revolutions are as 1 to 3¼. When a heavy weight is to be raised, the large wheel is used, and a slow motion is imparted to it; for a light weight, the small wheel is used, and the speed is doubled, the engine running at a uniform rate. A brake-lever operated by the foot is used to cause a brake to bear upon the face of the drum-wheels, and by this means the load can be lowered or held at any desired point. The same may be done by graduating the pressure upon the hand-levers. It is claimed that in these machines the power required is less than when using cogs; and the unpleasant noise of cogs, as well as danger from their breaking by overstraining or accident, is entirely avoided. No concussion or jar results from throwing the drum into or out of gear, either when loaded or light. The following table is based on 50 lbs. steam-pressure:

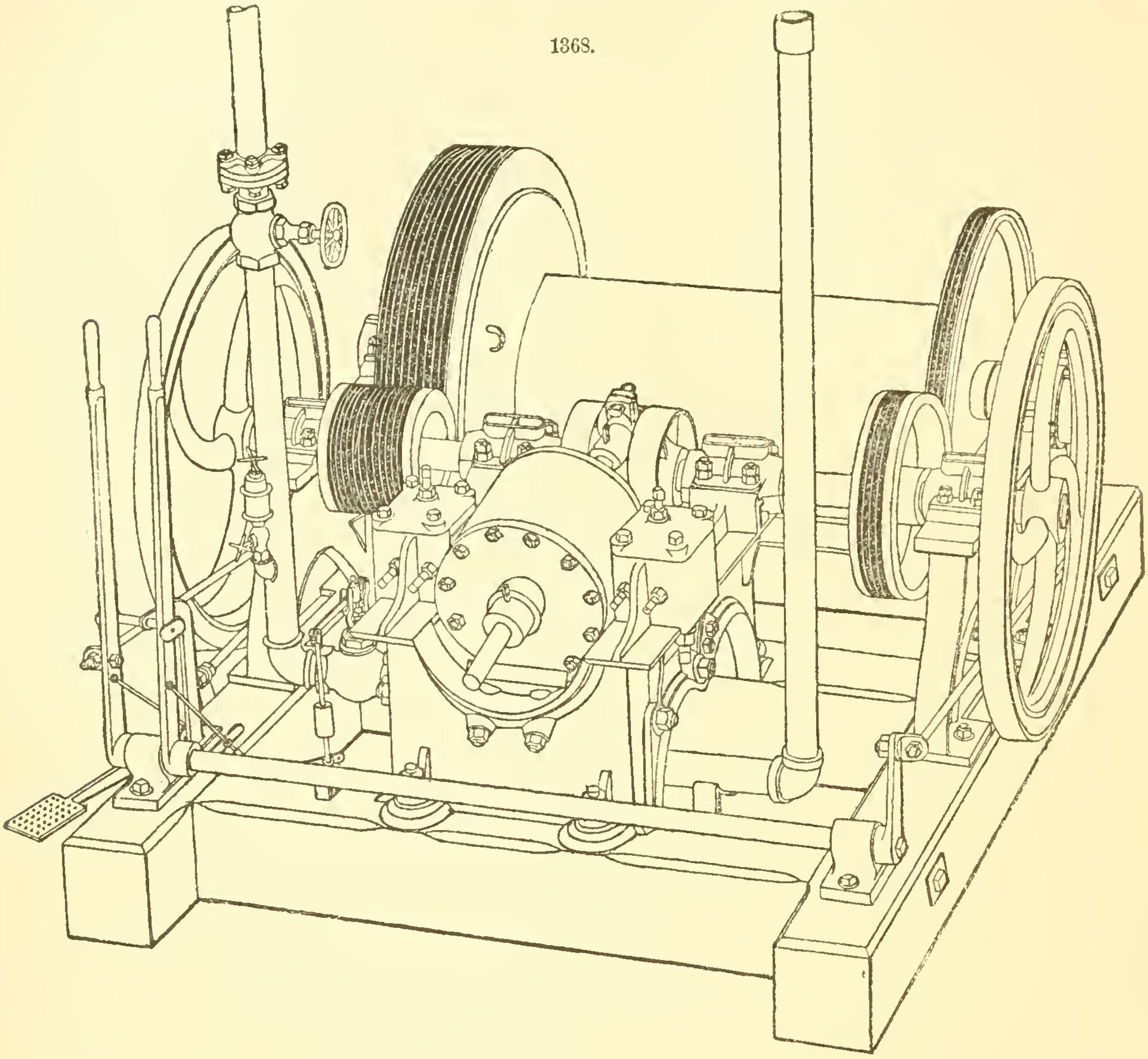
*Table showing Dimensions, Speed, and Loads raised by Steam Hoisting Engines.*

| POWER OF | | DRUM. | | DIAMETER OF MAIN | | DIAMETER OF FAST | | DUTY OF MAIN GEAR. | | DUTY OF FAST GEAR. | | WEIGHT OF MACHINE. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Engine. | Boiler. | Diameter. | Length. | Wheel. | Pinion. | Wheel. | Pinion. | Amount Raised. | Speed per Minute. | Amount Raised. | Speed per Minute. | |
| | | Inches. | Inches. | Inches. | Inches. | Inches. | Inches. | Lbs. | Feet. | Lbs. | Feet. | Lbs. |
| 5 HP | 5 HP | 6 | 27 | 30 | 4 | 26 | 8 | 1,500 | 60 | 750 | 120 | 3,150 |
| 8 HP | 8 HP | 8 | 27 | 30 | 4 | 26 | 8 | 2,000 | 75 | 1,000 | 150 | 3,650 |
| 12 HP | 10 HP | 8 | 30 | 36 | 6 | 30 | 12 | 2,800 | 85 | 1,200 | 200 | 5,200 |
| 15 HP | 15 HP | 8 | 30 | 36 | 6 | 30 | 12 | 3,500 | 85 | 1,500 | 200 | 6,200 |

An improved portable hoisting engine, adapted for the removal of cargoes from vessels, etc., made by J. S. Mundy, is represented in Fig. 1370. The apparatus is mounted on wheels so that it

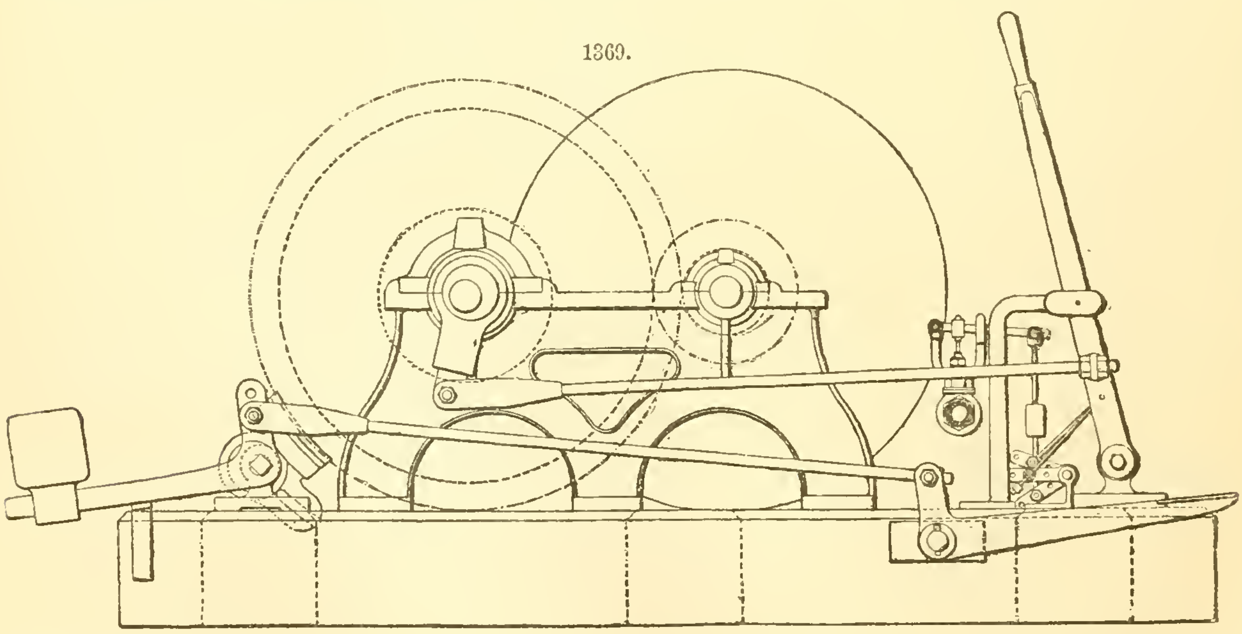
can be easily moved from place to place. The engines have plain slide-valves, worked by an eccentric direct from the main shaft. There are locomotive slides and cross-head of simple construc-

1368.



tion. Both engines are supplied with steam from the same boiler, which is fed by a steam-pump attached to it on one side and an injector on the other. Fig. 1371 shows a section of the friction-drum used in these machines. The drum is cast in one piece. The large gear is made with

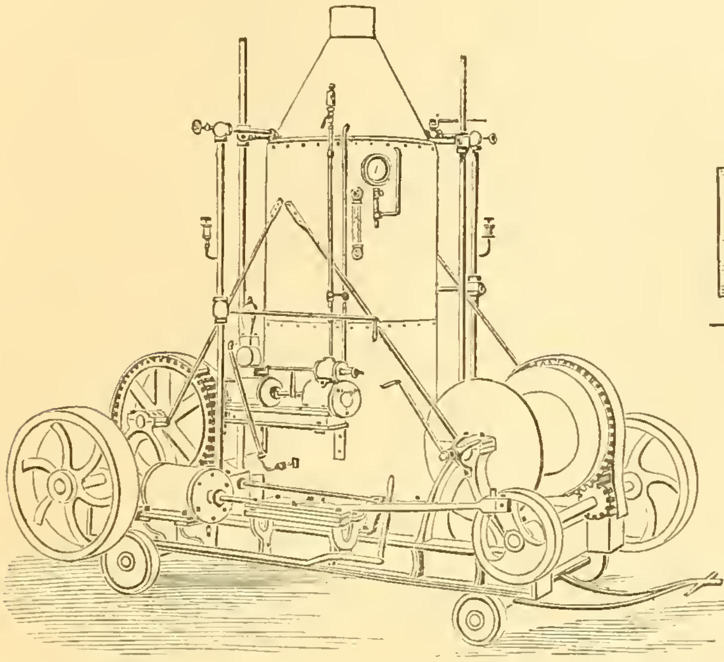
1369.



holes or pockets in the side to receive plugs of hard wood, that are fitted in and turned off to receive the cone-flange of the drum. The spiral spring between the gear and drum forces the drum

off the wood when relieved by the screw and pin at the other end. This can be used separate from the engine by the application of a belt on the pulley on the lower shaft, for hoisting in warehouses, stores, coal yards, or in any place where there can be power attached. The friction-gearing serves

1370.



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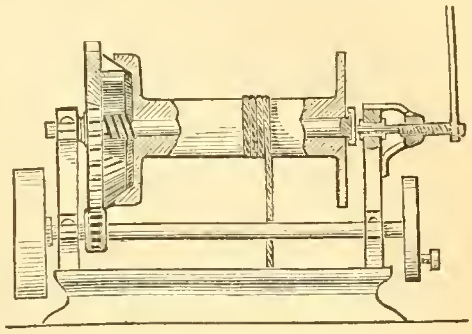
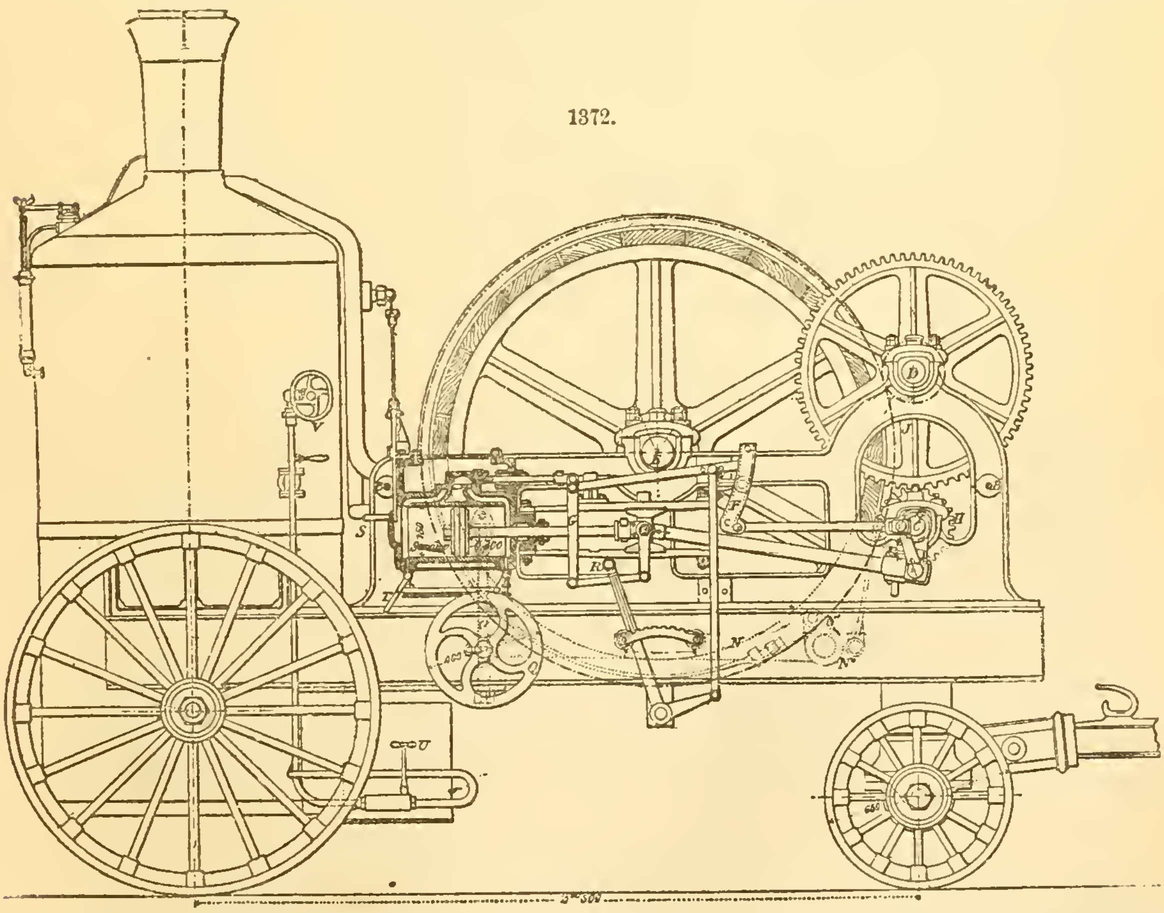


as a brake in lowering fast or slow, at the option of the operator.

Fig. 1372 represents a portable winding engine of Belgian construction, specially designed for temporary use at the shafts of mines, where the regular winding machinery has broken down, or for use in raising pump-gears, etc., at shafts not fitted with fixed hoisting gear. It is proportioned for raising a load of $1\frac{1}{2}$ ton from a depth of 1,650 to 1,950 feet, the rope used being 0.8 inch in diameter, and weighing 4 lbs. per yard. The apparatus consists of a pair of wrought-iron frames of **I** section, mounted on iron wheels adapted for traveling on ordinary roads. On the top of the frames just mentioned are mounted a pair of cast-iron frames carrying the engines and winding gear. The engine cylinders, which are $7\frac{1}{16}$ inches in diameter, with $11\frac{13}{16}$ inches stroke, are fixed to the outer sides of the cast-iron frames, as shown on the plan, the connecting-rods taking hold of cranks at the end of the shaft $C$. On this shaft is a pinion $H$, which

1372.

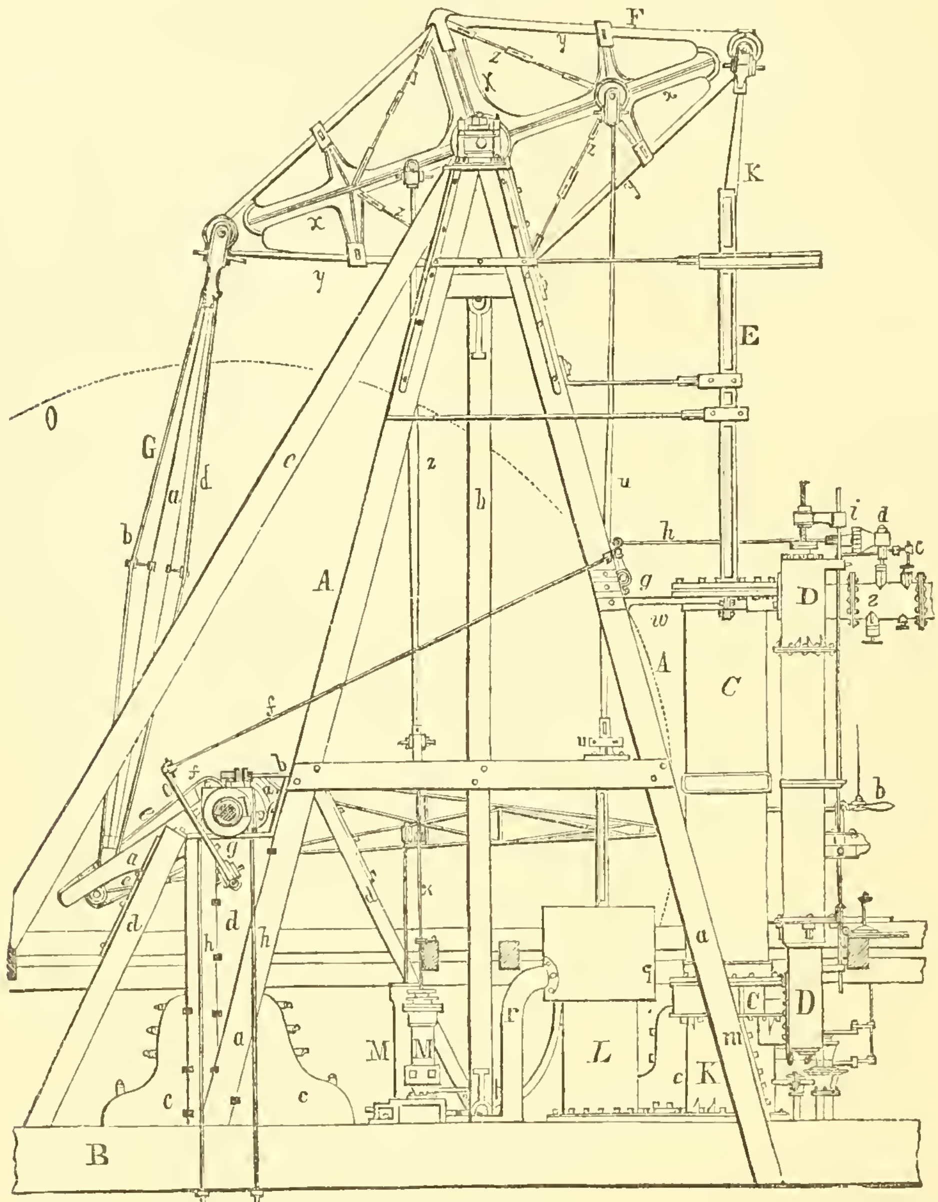


gears into a spur-wheel $J$, on a second shaft $D$ placed directly above the crank-shaft. This second shaft $D$ also carries a pinion $K$, which gears into the spur-wheel $L$ bolted to the rope-drum $M$. This drum $M$ is 4 feet $7\frac{1}{8}$ inches in diameter and 1 foot $7\frac{11}{16}$ inches long, and it can be divided into two by

a movable division ring, when it is desired to employ two ropes. The total ratio of the gearing is 18 : 1, the engine making 18 revolutions to one of the drum.

ENGINES, STEAM, MARINE. 1. The American River-Boat Engine.—The beam-engine with wooden gallows-frame is a form of engine peculiar to American practice, found principally in steamboats navigating the eastern rivers and sounds, and used to some extent in coasting steamers and boats on the great lakes. The modifications made in its construction of late years have been very

1373.




Scale.—¾ inch = 1 foot.

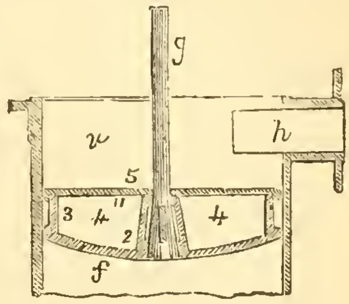
small. The various parts and general construction of the engine are fully shown in the following illustrations.

Fig. 1373 is a side elevation of the engine. Fig. 1374 is an end elevation exhibiting the steam-chests, the cylinder, and the parallel motion. Fig. 1375 is a vertical section of the steam-cylinder, the condenser, the bed-plate, and the air-pumps. Fig. 1377 is a plan of the bed-plate, showing the passage connecting the condenser with the air-pump, and the opening by which the foot-valve is introduced to its place. Fig. 1378 is a transverse section of the steam-chests, showing the arrangement of the balance-valves. Fig. 1379 is a plan of the steam-chest, and of the cylinder with the lid removed. Figs. 1380 and 1381 are views of the traverse-shaft for working the valve-lifters. Figs. 1382 and 1383 are face and edge views of the crank, showing the method of binding it by a wrought-iron strap. Figs. 1384 and 1385 are front and side views of the connecting-rod, showing the method of bracing it by wrought-iron rods. Figs. 1386, 1387, 1388, and 1389 are elevations and plans of the crank-shaft and main centre pedestals, showing the attachments for securing the blocks to the framing.

The following are the literal references: *A* is the principal frame, which supports the main centres of the beam, and also the bearings of the crank-shaft. *B* are the keelsons. *a a*, the fore and aft legs of the frame. *b*, the upright post under the main centre. *c*, oak-knees, by which the legs are secured to the keelsons. *d*, timbers which support the crank-shaft bearings; the fore and aft timbers are placed obliquely to strengthen the support. *e*, the back-stay for further securing the main centre. *C* is the steam-cylinder, and *C'* is the cylinder bottom. *f*, the piston; the under side of it, 1, is a solid web, rounded and in one piece with the centre 2 by which it is keyed to the

rod, and with the circular flange 3 at the circumference, upon which the packing is laid. These three parts are connected together by stiffening flanges, 4; and the whole is covered in by a flat plate, 5, which holds down the packing, and is bolted to the body of the piston. *g*, the piston-rod. *h h*, the steam-ports; the under port is formed in the cylinder bottom, which, it will be observed, is hollowed out to the form of the under side of the piston. *i*, the clutch and cross-head, keyed to the upper end of the piston-rod. *k*, the links connecting the cross-head to the working-beam. *D* are the steam-chambers, in which are placed the valves for regulating the motion of the steam into and out of the cylinder. *l l*, the chambers whence the steam is admitted to the cylinder. *m m*, the chambers into which the steam is discharged from the cylinder. *n n*, pipes connecting the upper and under chambers, bolted fast to upper chambers, but connected to the under chambers by expansion joints. *o*, the steam-valves, and *p*, the exhaust-valves, fixed in pairs on the spindles, and denominated equilibrium or balance-valves. *q r*, the valve-spindles, having their lower ends guided in inverted caps, introduced through the under sides of the steam-chests; their upper ends pass through stuffing-boxes, and are connected on the outside to the brackets on the lifting-rods. *s*, the steam-pipe from the boiler, furnished with two valves: one of them, *c''*, is the throttle-valve; the other, *d''*, is the cut-off valve; the latter is worked by a cam fixed on the crank-shaft, which works the lever *e''*, the fulcrum of which is fixed on the

1376.



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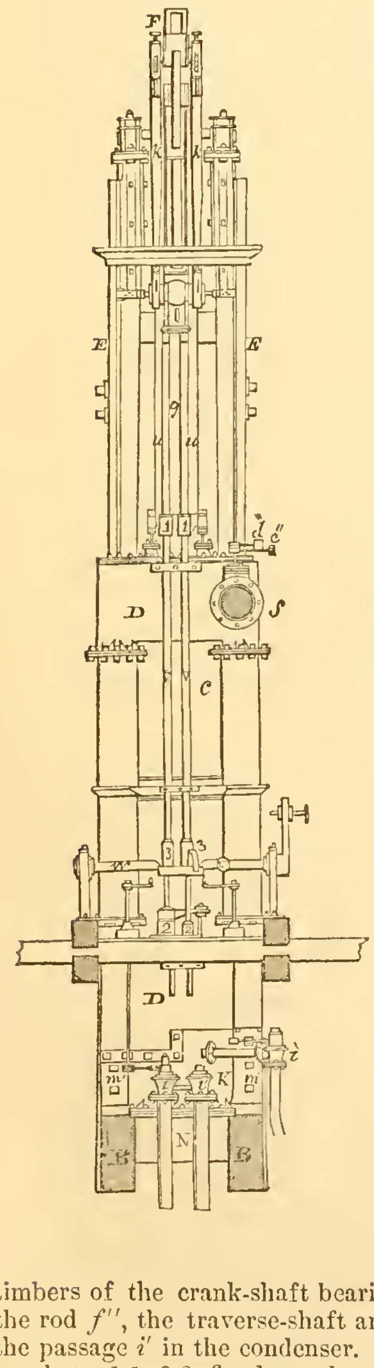

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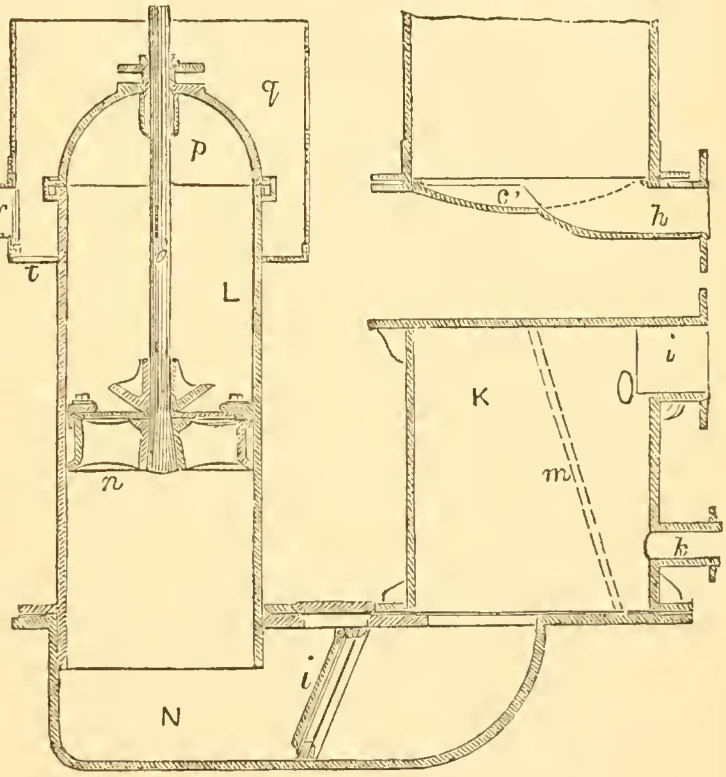

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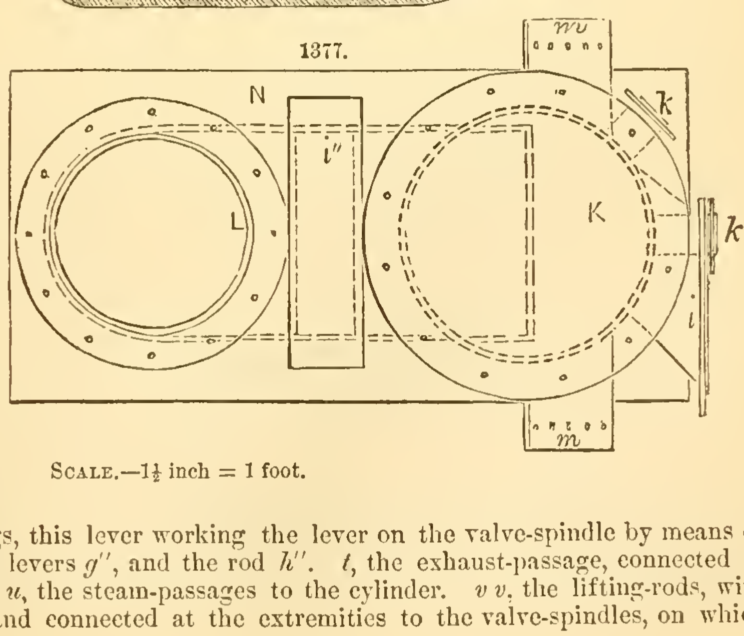
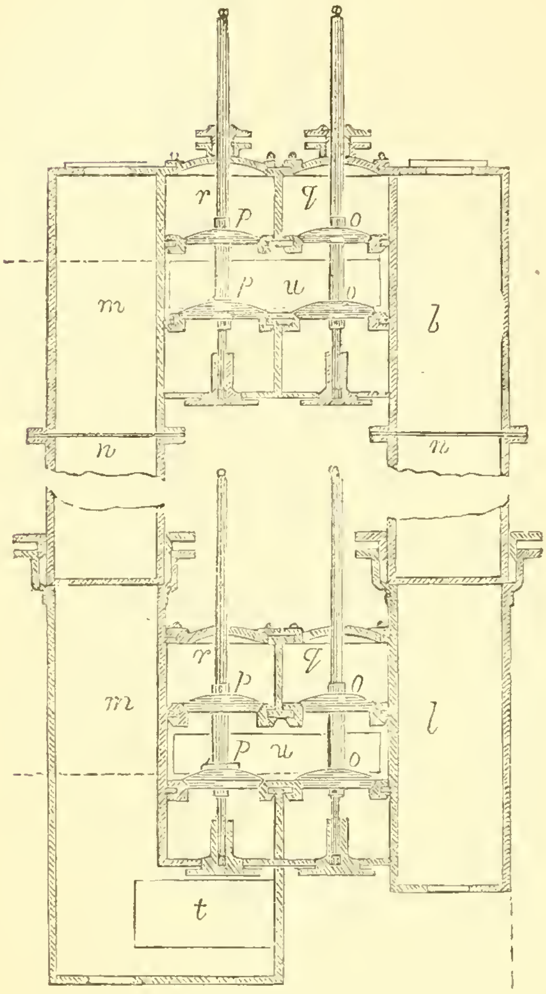


SCALE.—1½ inch = 1 foot.

timbers of the crank-shaft bearings, this lever working the lever on the valve-spindle by means of the rod *f''*, the traverse-shaft and levers *g''*, and the rod *h''*. *t*, the exhaust-passage, connected to the passage *i'* in the condenser. *u u*, the steam-passages to the cylinder. *v v*, the lifting-rods, with brackets, 1 1, 2 2, fixed on them, and connected at the extremities to the valve-spindles, on which

1378.

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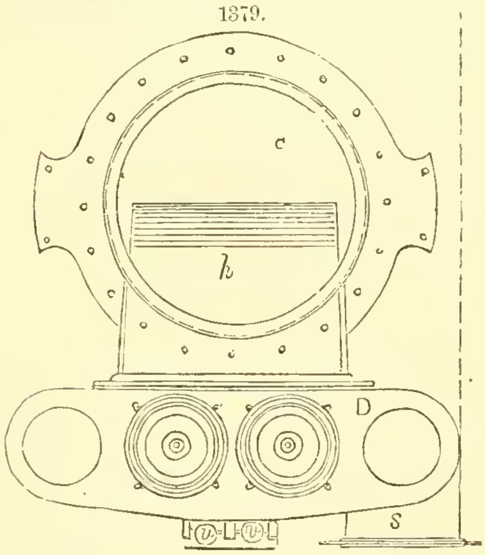


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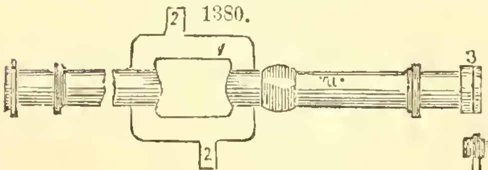


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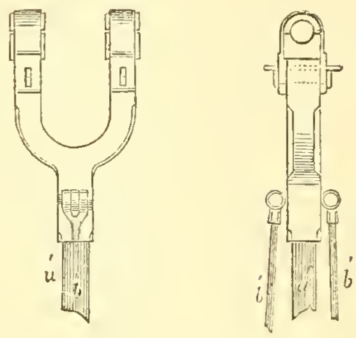

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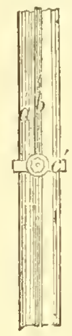

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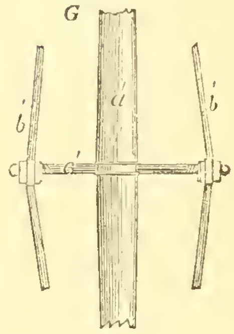


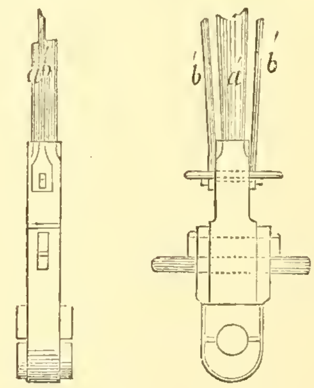

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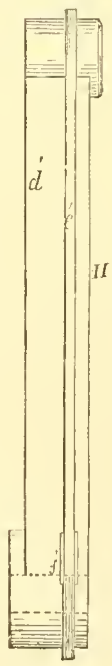


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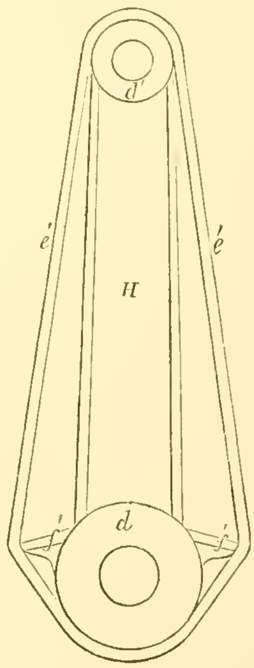
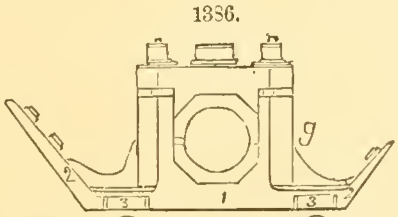


they are adjusted by nuts; 3 3, the lifting faces. *w*, the traverse-shaft: 1, the lifting-frame; 2, the lifters; 3, the eccentric-rod lever. (See Figs. 1380 and 1381.)

The operation of the balance-valves and their peculiar advantages are as follows: Referring to Fig. 1378, it will be observed that the valves are arranged in pairs, keyed on distinct spindles, and that each pair, therefore, is moved as one valve; further, the valves in each pair are of unequal diameters, the upper valves *o*, on the steam side, being larger than the under valves, and, on the contrary, the under valves *p*, on the exhaust side, larger than the upper ones. And here the peculiar and elegant adjustment is shown. The common puppet-valve sustains the full pressure of the steam on its exterior surface, which must therefore be overcome before the valve can be opened; but in the balance-valve the steam-pressure is made to balance itself (hence the name) as it enters the steam-port from both above and below. The upper valve in each pair on the steam side is larger than the under by as much as will afford, by the difference of pressures upon them, sufficient force, in conjunction with the weight of the valves, to shut them steam-tight in their seats. *Vice versa*, the *under* valve in each pair on the exhaust side is the larger of the two, so that, by the resulting tendency of the pressure of the steam from *within*, when entering the cylinder through the steam-valve, the exhaust-valve may be kept shut when required. Thus, it is clear that by regulating the relative diameters of the valves in each pair, the absolute difference of the areas of surface of each exposed to the steam-pressure may also be regulated, and consequently also the amount of pressure effective in shutting them. In the present instance, the valves are 10 inches and 9 inches respectively in diameter; therefore, the steam-pressure effectively exerted in shutting them is that due to a surface equal to the difference of these areas, or to 15.2 square inches. Let the steam-pressure be 50 lbs. on the inch, then the acting pressure will amount to $15.2 \times 50 = 760$ lbs., or, the weight of the valves being added, say 840 lbs. This will, indeed, appear little when it is considered what a common puppet-valve would require. If the puppet-valve were 11 inches in diameter, it would be subject to a pressure of 4,750 lbs. The slides also, such as are used in British engines, weigh 3,920 lbs., without the friction of the faces

1386.



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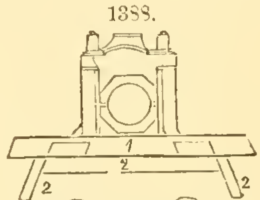
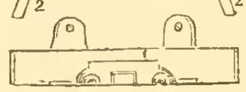
1388.





1389.

being taken into account. But, in fact, as the starting lever has a power of 6 to 1, the resistance to be overcome by the engineer in starting is only 140 lbs.

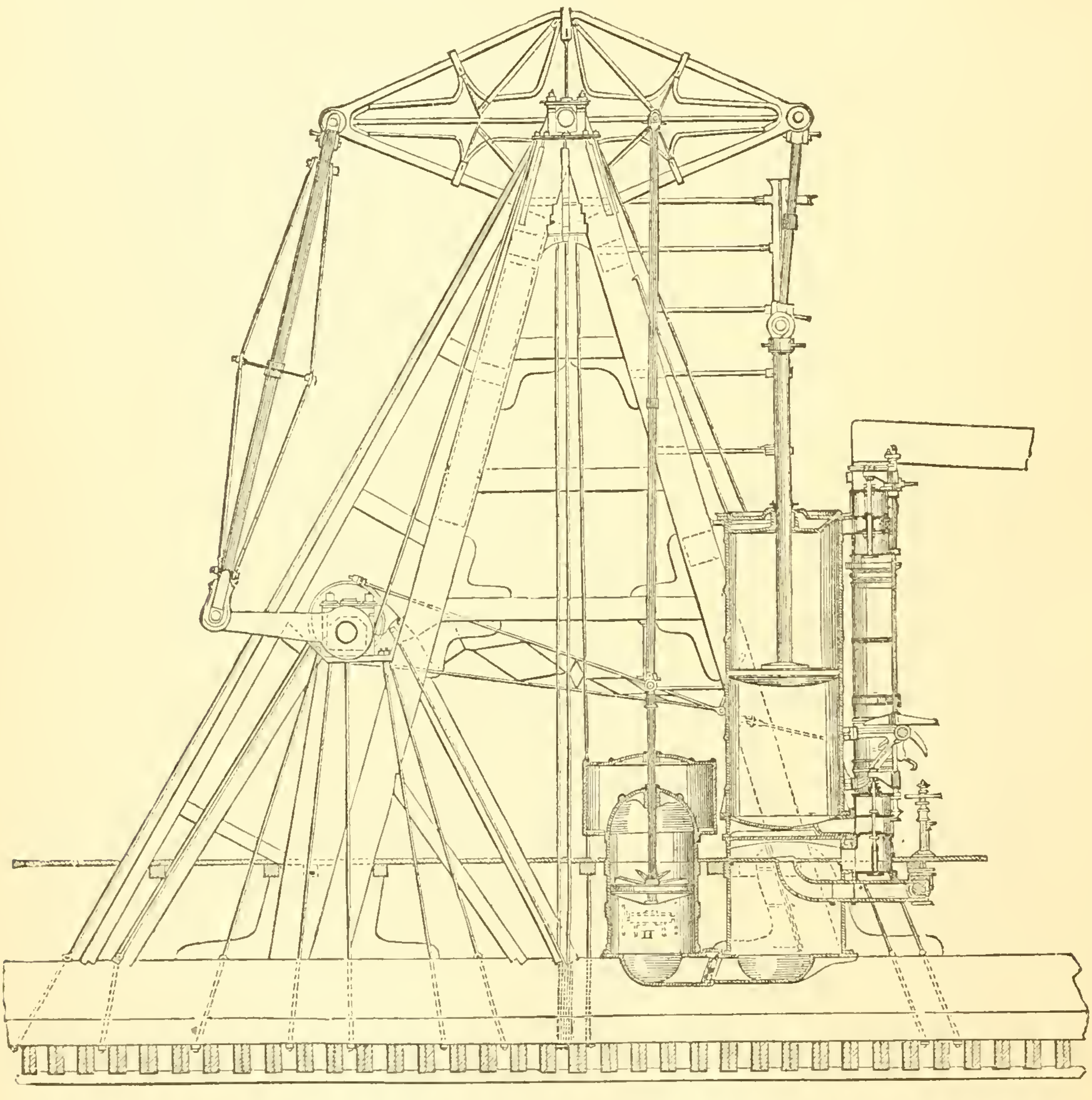
*E* are the parallel guides for the cross-head of the piston-rod. These, the cross-head, and the links *k*, constitute the parallel motion of the engine. The guides *E* are bolted to the projections on the cylinder flange, seen in Fig. 1379, and are stayed to the frame *A* by wrought-iron ties, and a small cast-iron cornice near the top. *F* is the main lever of the engine. *x*, a cast-iron centre, strung with tension-rods. *y*, tension-rods of wrought-iron, which are strapped to the centre-piece at the middle, the extremities, and the intermediate points. *z*, additional tension-rods, strengthening the intermediate points where the air-pump and feed-pump rods are connected. The main centre-pedestals are represented in elevation and plan in Figs. 1388 and 1389: 1, the sole; 2 2 2, flanges for securing the bearings more steadily to the frame. *G*, the connecting-rod, constructed of wrought-iron. *a'*, the rod, fitted with straps at the ends for embracing the bushes. *b' b'*, tension-rods for stiffening the main rod, and preventing the effects of vibration. These rods are jointed at the upper ends to the main rod, held in tension at the middle by the strut *c'*, which is screwed at the extremities to regulate the tension of the rod, and keyed up at the under ends. *H* is the crank, composed of a cast-iron body and a wrought-iron binding strap. *d'*, the cast-iron centre, in which the holes are formed for receiving the ends of the crank-shaft and the crank-pin; its form in section is that of a web terminated on both sides by flanges. *e'*, a wrought-iron tension-rod in one piece, passing entirely round the crank. *f' f'*, horns cast upon the crank for the purpose of stretching the strap *e'*, the strength being thereby rendered available. The fellow of this crank, which is seen in the general elevation, Fig. 1373, is differently formed, being made solid at the end, and provided with bolt-holes, through which a strap embracing the crank-pin is introduced and screwed upon the other side. By this arrangement, the crank-pin may at any time be readily disengaged from the crank, and the parts are more easily put together. *I* is the crank-shaft. *g'*, the pillow-block: 1, the sole of the block resting on the timbers; 2 2, flanges for securing the block to the framing by bolts and nuts; 3 3, lugs cast on the sides of the sole, through which holding-down bolts are passed, which are secured to the keelsons. *a''*, the eccentric for working the balance-valves. *b''*, the eccentric-rod, having its length divided, at a point near the handle, into two parts jointed together, the longer and heavier part next the eccentric being supported on a vibrating joint. By this means it becomes an easy matter to disengage the rod from the lever of the traverse-shaft, which is done by means of a small rope attached to the extremity of the rod. *K* is the condenser. *i'*, the exhaust-steam passage. *k'*, the injection passages. *l'*, the injection cocks. *m' m'*, the flanges by which the condenser is bolted to the principal frame. *L* is the air-pump. *n'*, the bucket, the construction of which is obvious from the section, Fig. 1375. *o'*, the bucket-rod. *p'*, the floating-top or delivery valve, which is

cast hollow, and has its lower edges, where it rests on the air-pump, filed true, so as to fit and form a good joint. This serves a twofold purpose, namely, as the air-pump lid and the delivery valve. Its action is simple and ingenious; for when the bucket arrives at a certain height, the lid is raised and the water flows out all around, thus discharging more effectually and rapidly than by the common valve, and requiring little or no power to discharge, having only the lids to raise. $q'$, the hot-well, made of copper, and riveted to the air-pump by means of a vertical flange. $r'$, the waste-pipe. $s'$, the feed-pipe. $t'$, the pipe for drawing off the water from the hot-well. $u'$, the rod from the beam, which drives the air-pump rod. $v'$, the guide for the cross-head of the air-pump rod, stayed to the principal frame by means of the bracket $w'$. $M$ is the feed-pump. $x'$, the pump-rod, moving in the guides $y'$ $y'$, driven from the beam by the rod $z'$. $M'$ is the bilge-pump. $N$ is the bed-plate. $i''$, the foot-valve.

The following are the principal dimensions of an engine of this class built for the steamer Osceola: Diameter of cylinder, 31 inches; length of stroke, 11 feet; length of beam, 17 feet 9 inches; length of connecting-rod, 21 feet 1 inch; length of links, 7 feet 6 inches; height of beam from keelson, 31 feet; width between guides of piston-rod, 3 feet $6\frac{1}{2}$ inches; diameter of paddle-wheel, 28 feet; number of strokes per minute, 24; velocity of piston in feet per minute, 528.

Fig. 1390 represents the beam-engine of the steamboat New World, a remarkably fine vessel which some years since plied between Albany and New York on the Hudson River. She was de-

1390.



stroyed by fire. Her average running speed between the points named, a distance of 146 miles, was 9 hours. Thirteen landings were made, which involved a loss of time of at least 5 minutes each, leaving 7 hours and 55 minutes as the average running time, or about $18\frac{1}{2}$ miles per hour. This speed was often exceeded for short periods, the rate of 20 miles per hour being frequently attained. The dimensions of the New World were: Length, 375 feet; breadth, 36 feet; breadth over guards, 69 feet; depth of hold, 10 feet 6 inches. She was constructed of wood.

The cylinder of this engine was 76 inches in diameter. The valves were of the type already described. The valve-gearing was the Stevens cut-off, a device now commonly used, which may be

described as follows: There are four lifter-rods, which are turned bars of wrought-iron, placed in front of the steam-chests. They are made to move vertically up and down through guides which are cast or bolted to the chests and side-pipes. On the lifter-rods are keyed eight projecting arms, called lifters. Four of these embrace the extremities of the valve-spindles, which are screwed and provided with double jam-nuts. The spindles pass quite loosely through the ends of the lifters, and the jam-nuts are adjusted so as not to bind them: there is thus an allowance made for any slight lateral motion which inaccuracy of adjustment or wear of guides may render requisite. The four remaining lifters are likewise keyed upon the rods, and they are placed directly over the levers on the rock-shafts, from which they receive their motion. There are two rock-shafts, one for the steam and one for the exhaust valves, and they are worked by separate eccentrics. On the shafts there are four levers, by which the lifters and rods are raised, and they are curved on their working faces, so that their action is rendered perfectly smooth and noiseless. By the reciprocating or rocking motion of the shafts, the lifter-rods, and with them the valves, are alternately raised and lowered. The exhaust-valve levers are of a length just sufficient to give the requisite amount of lift and lead, and they are so adjusted on their rock-shaft that the moment one rod is fairly down the raising of the other commences. The steam-levers are considerably longer, and are placed upon their rock-shaft in a position inclined to one another, so that an interval, longer or shorter, occurs between the falling of one rod and the rising of the other. During this interval both valves are down, and the steam is of course shut off from the piston. This apparatus then constitutes the expansive or cut-off gearing, and it may be varied at pleasure by simultaneously adjusting the respective positions of the eccentric on the paddle-shaft, of the two levers on the rock-shaft, and of the pin in the eccentric-lever. This latter has a slot in it, in which the pin travels, so that it can be moved to or from the shaft, and fixed as required. By advancing the eccentric, and lowering the extremities of the levers, the steam will be earlier cut off, and *vice versa*. The amount of lift may be regulated by moving the eccentric-pin. The movement of the rock-shaft in the interval during which the valves are down is very considerable, especially in a high expansion, and this, added to the additional amount of movement by which the valves are lifted the requisite height, makes the total angular motion of the rock-shaft very great, and therefore an eccentric of corresponding throw is required. Another variety of gear in frequent use has but one rock-shaft and eccentric, with but two lifter-rods. The exhaust-lifters and their action are precisely the same as in the gear already described. The steam-lifters, which are like the others keyed to the rod, have spring catches fitted at their extremities, which lock into the valve-spindles when down, and which are released at the proper time by coming in contact either with an adjustable stop or with a reciprocating arm, moved by the engine. The valves then fall by their own weight. To prevent damage arising from the concussion, a contrivance called the dash-pot is made use of: this consists of a small cylinder containing water, and a piston which fits it loosely, and is attached to the valve-stem. The height of the water is so adjusted that the piston touches or dashes upon it before the valve reaches its seat; the momentum is thus effectually overcome, and injury to the surfaces of contact completely prevented. The rock-shaft, lifters, and levers are of cast-iron, turned and finished bright. The outer supports of the rock-shafts are bolted to the side-pipes, and the middle support, which is common to both shafts, is fastened to brackets cast on the cylinder.

The following abstract of a report by Theron Skeel of the performance of the Mary Powell, one of the finest day-boats now (1879) running on the North River, is of unusual interest, as presenting probably the most complete data that have been collected relative to the performances of a vessel of this type:

*Dimensions of Hull.*—Length on water-line, 286 feet; length over all, 294 feet; beam at water-line, 34 feet 3 inches; beam over all, 64 feet; depth of hold, 9 feet; height from main deck to promenade deck, 10 feet; height from promenade deck to upper deck, 8 feet; draught of water, at mean load of passengers and coal, 6 feet; midship section (estimated), 200 square feet; displacement (estimated), 28,000 cubic feet; projected area of surface resisting head wind, 2,000 square feet.

*Personnel* (*exclusive of steward's department*).—1 captain, 2 engineers, 4 firemen, 4 deck-hands, 2 pilots, 1 clerk, 1 baggage-master; total, 15.

Length of trip, 5 hours and return. Average number of passengers, 250. Average fare per mile, 1¼ cent.

*Engine.*—Diameter of cylinder, 6 feet; stroke of piston, 12 feet; diameter of piston-rod, 8 inches; diameter of air-pump, 3 feet 4 inches; stroke of air-pump, 5 feet 2 inches; diameter of shaft, 1 foot 3 inches; diameter of journal, 1 foot 3⅝ inches; length of journal, 1 foot 5 inches; diameter of crank-pin, 8¾ inches; length of crank-pin, 10¾ inches; diameter of wheels over tips of buckets, 31 feet; length of each bucket, 10 feet 6 inches; width of each bucket, 1 foot 6 inches; number of buckets to each paddle-wheel, 26; greatest immersion of outer edge of bucket at mean draught, 3 feet 6 inches; displacement of piston per revolution, 676 cubic feet; of clearance at both ends of cylinder, 25 cubic feet; diameter of steam and exhaust-valve openings in steam-chest, 1 foot 2¾ inches.

*Boilers* (*two in number, steel—dimensions of each*).—Length over all, 26 feet; length of cylindrical shell, 16 feet 1 inch: length of fire-box, 9 feet; width of fire-box, 11 feet; diameter of cylindrical shell, 10 feet; diameter of steam-drum, 5 feet 10 inches; diameter of steam-chimney, 4 feet 2 inches; height of steam-drum, 12 feet; number of furnaces, 2; width of furnaces, 4 feet 10 inches; length of furnaces, 8 feet; length of direct flues, 9 feet 1 inch; diameter of tubes (external), 4½ inches; grate surface (two boilers), 152 square feet; heating surface, 2,660 square feet; superheating surface, 340 square feet; cross area of lower flues, 23.2 square feet; cross area of tubes, 17.2 square feet; cross area of steam-chimney, 25 square feet; diameter of smoke-stacks (two), 4 feet 6 inches; height above grate, 68 feet; number of direct flues and diameter: two flues, 14 inches; six flues, 16 inches; two flues, 9 inches.

*Results for Three Years.*

| DETAILS. | 1875. | 1876. | 1877. |
|---|---|---|---|
| Number of observations | ...... | 12 | 27 |
| Running time from Newburgh to New York, or return, minutes | 185.5 | 187.5 | 182 |
| Distance run in above time, miles | 60 | 60 | 60 |
| Revolutions per round trip from Rondout to New York, and return | ...... | 13,100 | 12,190 |
| Distance as above | 90 | 90 | 90 |
| Revolutions per minute from Newburgh to New York, or return | ...... | 21.3 | 21.77 |
| Speed in miles per hour " " " " | 19.3 | 19.2 | 19.8 |
| Coal per round trip, gross tons | 23.79 | 22.85 | 24.25 |
| Coal per revolution, pounds | ...... | 4.57 | 4.37 |
| Slip of wheels per cent. (calculated for centre of paddle) | ...... | 14.5 | 11.9 |
| Revolutions from Newburgh to New York, or return | ...... | 4,007 | 3,963 |
| Revolutions per mile from Newburgh to New York, or return | ...... | 66.8 | 66 |
| Revolutions per mile per round trip | ...... | 72.9 | 67.2 |

(In making the estimate of running time, the time lost at the landings was deducted.)

*Results for* 1877.

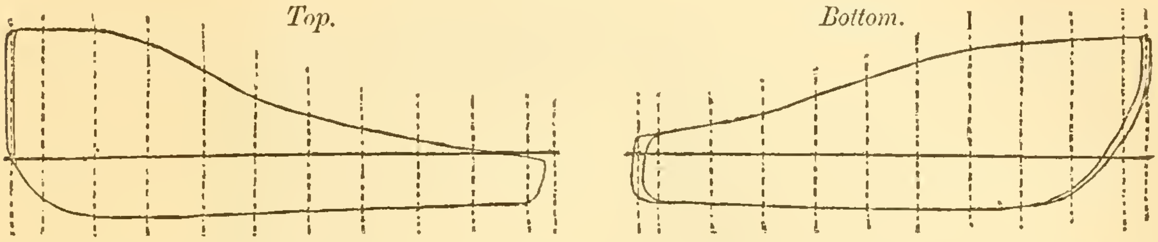
| | |
|---|---|
| Total number of miles run | 15,300 |
| *Hourly quantities.* | |
| Speed of boat in miles (5,280 feet) | 19.3 |
| Revolutions of engine | 1,306 |
| Pounds of coal consumed | 5,970 |
| " of combustible (ashes 16⅔ per cent.) | 4,870 |
| " of coal consumed per square foot of grate surface | 39.3 |
| " of combustible " " " | 32.8 |
| " of coal " " of heating surface | 2.25 |
| " of combustible " " " | 1.88 |
| *Temperatures.* | |
| Atmosphere | 70° |
| Hot-well | 120° |
| Feed-water | 120° |
| Chimney gas | (Zinc melts.) |
| *Pressures* (see indicator cards, Fig. 1391). | |
| Steam (pounds per square inch above the atmosphere) | 28 |
| Vacuum (inches of mercury) | 25 |
| Initial pressure (pounds per square inch above zero) | 40 |
| Pressure at cut-off " " " | 31.2 |
| " at end of stroke (pounds per square inch above zero) | 16.4 |
| Mean back pressure " " " | 5.6 |
| Pressure at end of cushion " " " | 40 |
| Mean total pressure " " " | 29.94 |
| " indicated pressure (pounds per square inch) | 24.34 |
| " net " " " (friction 1.5) | 22.84 |
| Point of cut-off, fraction of stroke | 0.47 |
| " where cushion commences, fraction of stroke | 0.8 |
| *Power.* | |
| Total horse-power | 1,899 |
| Indicated horse-power | 1,540 |
| Net " | 1,446 |
| Pounds of steam used per hour, from indicator diagrams | 42,000 |
| *Economic performance.—Boiler.* | |
| Pounds of water per pound of coal, from 120° | 7 |
| " " " " 212° | 7.8 |
| " " of combustible, from 120° | 8.2 |
| " " " " 212° | 9.1 |
| " per square foot of heating surface, per hour | 14 |
| *Engine.* | |
| Pounds of steam per hour, per total horse-power | 22.1 |
| " " " " indicated " | 27.3 |
| " " " " net " | 28.9 |
| " coal " " total " | 3.14 |
| " " " " indicated " | 3.87 |
| " " " " net " | 4.13 |

The results of experiments made to determine what proportion of the power of these boats is lost through the resistance of the air and wind on the decks and cabins show that this loss does not exceed 10 per cent. of the power applied. That is to say, when running through still air and still

water, about 90 per cent. of the power is absorbed in overcoming the resistance of the water and 10 per cent. in overcoming the resistance of the air. In this connection it must be remembered that of the total surface resisting the wind (2,000 square feet), a considerable portion, being the hull of the boat, the paddle-boxes, and smoke-stacks (at least 800 square feet), is necessary, and could not be reduced even if the upper decks were left off.

Among the finest illustrations of recent practice in the construction of side-wheel steamers are those built for the several routes between New York and the cities of New England, which traverse

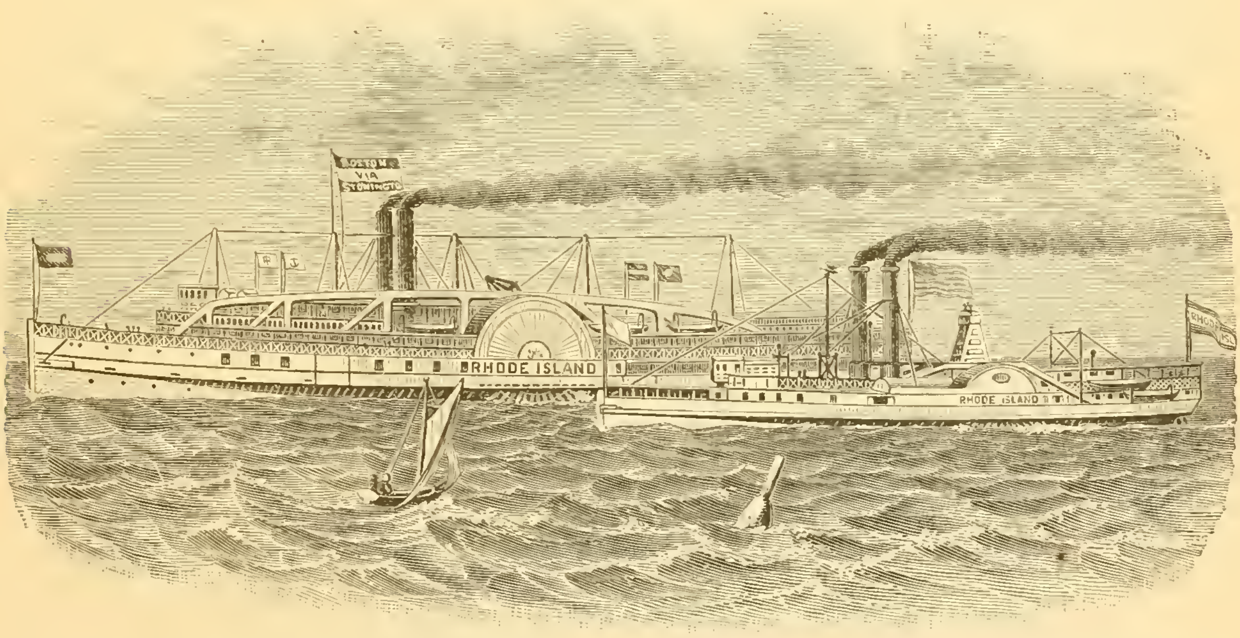
1391.




Long Island Sound. Fig. 1392 exhibits the form of one of these vessels, in comparison with a steamboat of the same type, but of the form constructed in 1836. The latter vessel was 325 feet long, 45 feet beam, 80 feet wide over the guards, 16 feet deep, and drew 10 feet of water. The engine had a steam-cylinder 90 inches in diameter and 12 feet stroke. In the Sound steamers Bristol and Providence the cylinders are 110 inches in diameter and 12 feet stroke. The engine of the Rhode Island is capable of developing 2,500 horse-power. The paddle-wheels are $37\frac{1}{2}$ feet in diameter and 12 feet in breadth. The weight of the hull is over 1,200 tons, of the machinery 625 tons. The best speed is 16 knots per hour at 17 revolutions per minute; average speed, 14 knots. The coal consumed is about 3 tons per hour, or $2\frac{1}{2}$ lbs. per horse-power per hour.

The steamboats on Western rivers have almost invariably horizontal non-condensing engines—an independent engine for each wheel in the case of side-wheel steamers, and two engines for stern-wheel boats. The connecting-rod is usually of wood, strapped with iron, and with a length of from three to four times the stroke. There are two steam- and two exhaust-valves, all single puppet-valves, worked by the action of cams on long lifting levers, the cams being moved by eccentrics on the shaft. Boilers with two flues, set in cast-iron fronts and with brick walls, very similar to the setting of

1392.



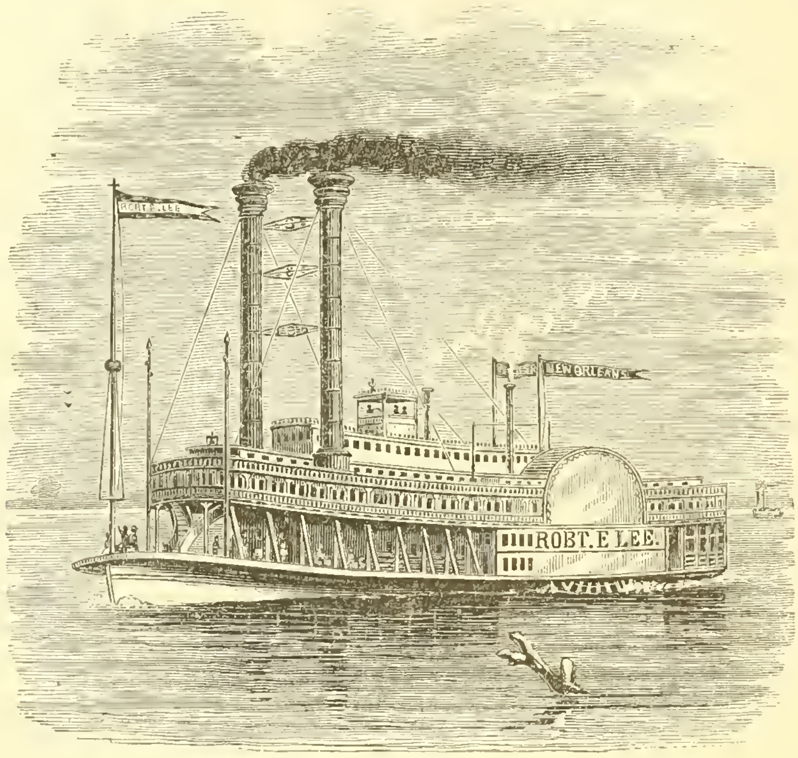

stationary boilers, are generally used. A description of these engines and boilers is contained in King's "Lessons and Practical Notes on Steam." A vessel of this class is represented in Fig. 1393. The largest steamer on the Mississippi is (1879) the Grand Republic. Her length is 340 feet, beam 56 feet, and depth $10\frac{1}{4}$ feet. The draught of water of this great craft is but $3\frac{1}{2}$ feet forward and $4\frac{1}{2}$ feet aft. The two sets of compound engines, 28 and 56 inches in diameter and of 10 feet stroke, drive wheels $38\frac{1}{2}$ feet in diameter and 18 feet wide. The boilers are of steel. A similar vessel, built on the Ohio, has the following dimensions: Length, 225 feet; breadth, $35\frac{1}{2}$ feet; depth, 5 feet; cylinders, $17\frac{3}{4}$ inches in diameter, stroke 6 feet.

For a paper on the "Construction of American River Steamboats," by Theo. Allen, C. E., see "Transactions of the American Society of Civil Engineers," 1874.

II. Earlier Forms of Marine Engines.—With few exceptions, vertical engines are used at present in large ocean steamers, the change having been made a few years after the displacement of the paddle-wheel by the screw in ocean navigation. The details of the older forms of engines, however, are not without interest, and some illustrations and descriptions are appended.

*Direct-acting engines* differ from the beam-engine simply in the method of taking the power from the piston-rod. In the one the head of the piston-rod is connected either directly with the crank, or by means of a connecting-rod or rods; in the other, the working-beam or great lever, vibrating on

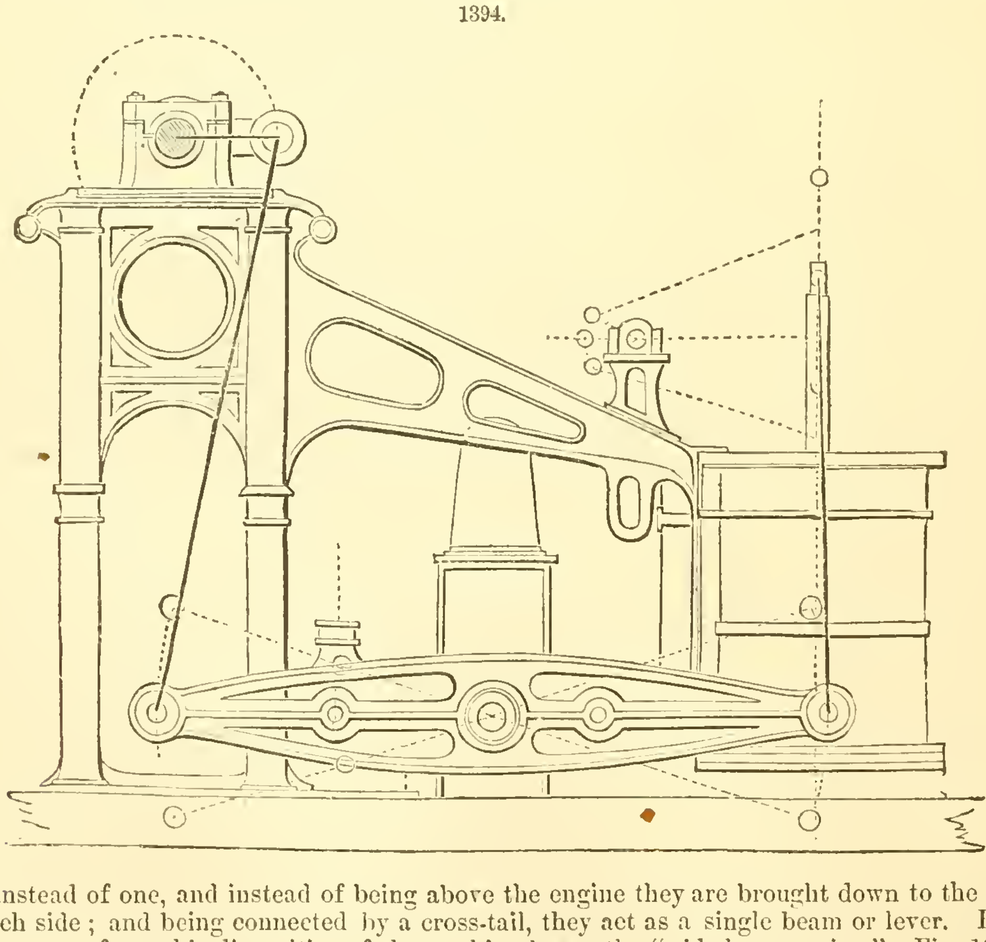
1393.




its centre, receives at one end the power from the piston-rod through the modifying action of "parallel-motion" rods, or plain slides, and communicates it to the crank-shaft by a connecting-rod attached to its other extremity.

The *side-lever engine* is a modification of the beam-engine. In our river and coast boats the working-beam or lever is above the engine, and single; but in the sea-going steamers two of these beams

1394.

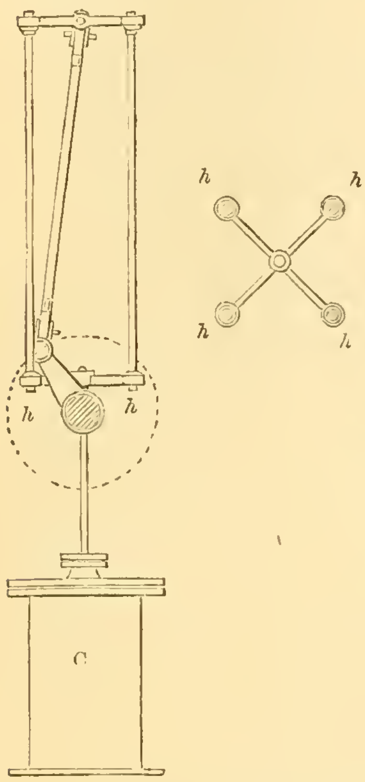


are used instead of one, and instead of being above the engine they are brought down to the bottom, one on each side; and being connected by a cross-tail, they act as a single beam or lever. Hence is derived the name from this disposition of the working-beam, the "side-lever engine." Fig. 1394 will

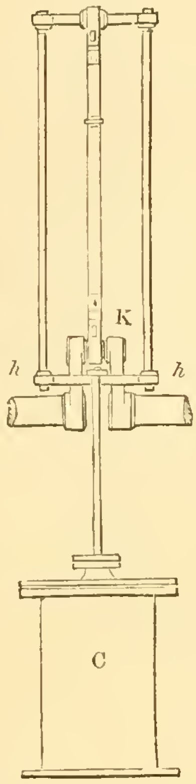
give an idea of the general appearance of the side-lever engine, in outline. The engines of the Collins line of steamers were of this description, and in fact the side-lever engine was used in the majority of ocean steamers fitted with paddle-wheels a few years ago.

Passing to the varieties of the direct-acting engine, we find that the attempt to produce engines

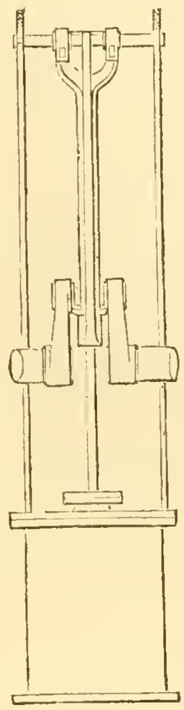
1395.



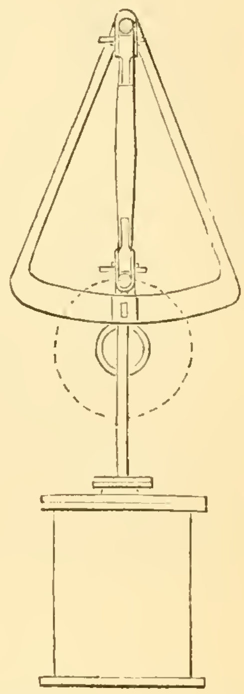

1396.




1397.



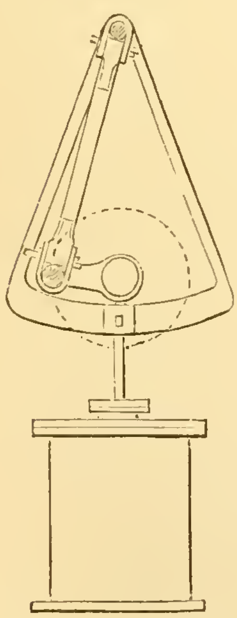
1398.



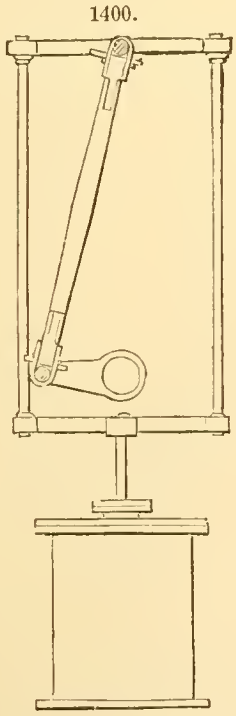
more compact and of less weight and bulk has extended the examples of this class of engines into an almost endless variety of modifications; scarcely any two are alike. Some engineers regard those engines only as direct-acting where the piston itself seizes the crank, without the intervention of any connecting-rods, as in the trunk and oscillating engines.

In the vertical direct-acting engine, the paddle-shaft is directly over the axis of the cylinder; but the method has the disadvantage of admitting only a short stroke and a short connecting-rod, and

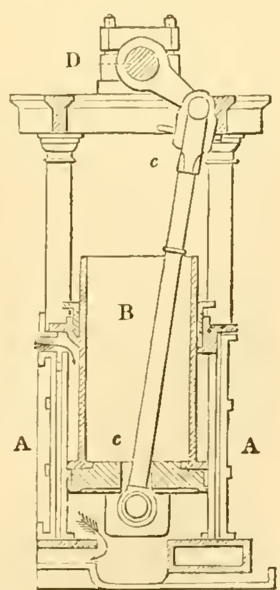
1399.



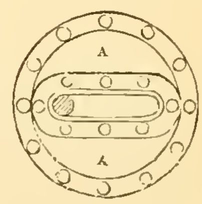
1400.



1401.




1402.




requires that the height of the axis above the bottom of the cylinder should be at least three times the length of the stroke. Thus one of the extremes, too short a connecting-rod, too short a stroke, or a paddle-axis too high above the floor of the vessel, is incurred.

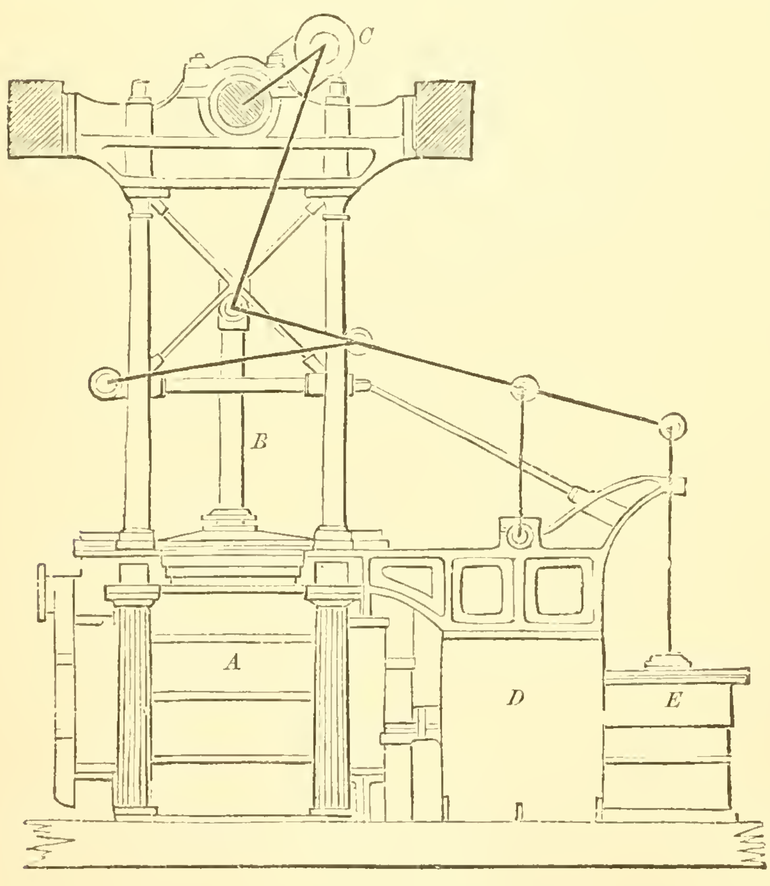
In this country the square engine, the first variety of the vertical engine, has its cylinder immediately over the axis and cranks, to which motion is communicated from the cross-head of the piston

by means of side-rods, the air-pump being worked by a separate beam connected with the cross-head by proper links; but this is equally unsuited to sea-going steamers on account of the height of the cylinder above the paddle-shaft. To obtain the object sought without incurring these evils, many descriptions of engine have been contrived; among others the *steeple engine*, so called, where the piston-rod is made forked, so as, passing round the shaft, to rise above it to a considerable height, from which again descends the connecting-rod to the crank. Figs. 1395 to 1400 illustrate the principle. The top of the piston-rod carries a four-armed cross-head *h h*, on each end of which stands a pillar *h h;* these four pillars again unite in another quadruple cross-head, sustained upright by a vertical guide; and it is from this summit that a connecting-rod descends to the crank *K*. In Figs. 1398 and 1399, which represent one form of the steeple engine, the piston-rod is seen united to a triangular frame, from the apex of which the connecting-rod descends to the crank. In Fig. 1400 this frame is shown to be square, and Fig. 1397 is the side view of both varieties.

Another method of accomplishing the direct connection without encumbering the deck is by the use of the *trunk engine*. The axis is placed at the height of half the stroke or more above the cylinder, and a connecting-rod unites immediately the crank-pin with the centre of the piston. In this way the connecting-rod, passing through the top of the cylinder, would allow the steam to escape but for a large trunk or casing with which it is surrounded, and which, passing through an opening of large area conceived to be steam-tight, rises and falls with the piston to which it is attached. In Fig. 1401, *A A* is the cylinder; to its piston is attached a trunk *B*, which works through a stuffing-box in the cylinder cover; to the piston the connecting-rod *c c* is attached. Fig. 1402 represents the top of the cylinder *A A*, with its stuffing-box and the trunk.

The Gorgon, Fairbairn, and Maudsley engines are English varieties of direct-acting engines, but little used in this country; they deserve a passing notice, as illustrative of the efforts made to reduce the dimensions of marine engines within the least possible limit. Fig. 1403 represents the *Gorgon engine*, in which *A* is the cylinder, *B* the piston-rod, *C* the crank, *D* the condenser, and *E* the air-pump. The chief peculiarity of the engine is its parallel motion for keeping the connecting-rod in vertical line. *Fairbairn's engine*, Fig. 1404, has a somewhat similar contrivance. Its arrangement in other respects is obvious from the drawing. Fig. 1405 represents *Maudsley & Field's engine*, designed for use where long connecting-rods could not be employed. It will be observed that the rods are connected by a T-plate *A*, to which is attached the connecting-rod *B*, which communicates with the paddle-wheel crank. *C* is the air-pump, worked by the beam *D*. The condenser is at *E* under the cylinders.

1403.

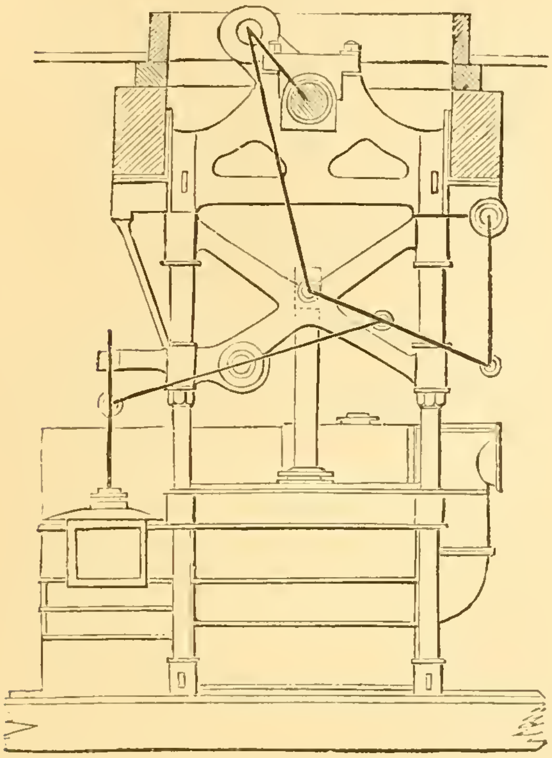



In the *oscillating engine* the connecting-rod is altogether dispensed with, the piston-rod being attached directly to the crank; and because the piston-rod, from this mode of attachment, must either be bent when motion ensues, or the top of the cylinder must move laterally, this is provided for by allowing the cylinder itself to vibrate in a small arc, effected by casting trunnions on to the cylinder near its middle, as an axis upon which it oscillates. The general arrangement of the oscillating engine is shown in Fig. 1406.

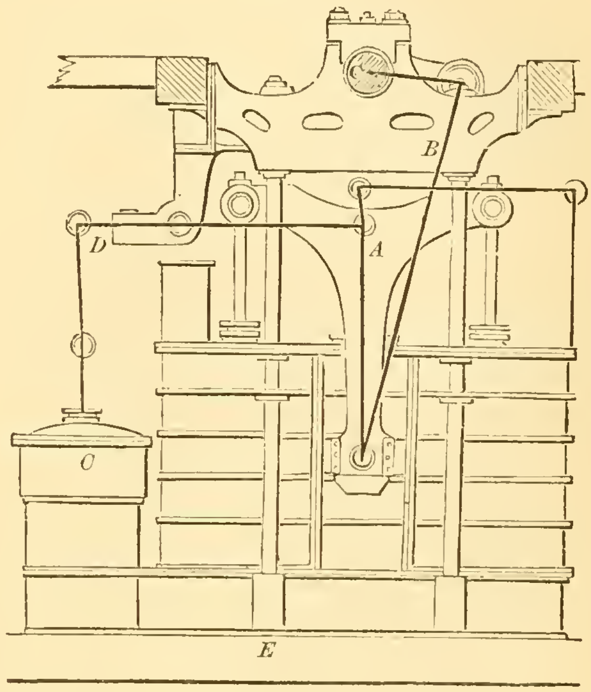
III. Screw-Propeller Engines.—Oscillating engines have been used to a considerable extent in ocean steamers, frequently being geared in screw vessels; but at present nearly all merchant steamers have vertical direct-acting engines, with inverted cylinders, while horizontal direct- or back-acting engines are more commonly used in war vessels, so that the machinery can be placed below the water-line. By far the largest number of modern marine engines are of the double-cylinder or compound variety. In this form, the steam, after being used in one cylinder, is exhausted either into a receiver or directly into one or more other cylinders, and acts in them before being discharged into the condenser. It is claimed by many that engines of this form are much more economical than simple engines (or engines in which the steam is exhausted into the condenser after acting in one cylinder); and in the files of technical journals will be found numerous comparisons that have been made in support of this view. There is no doubt that great saving has been effected in many cases by replacing the older forms of engines by those of the compound variety, and at the same time increasing the steam-pressure and piston-speed; but it is at least questionable whether equally favorable results might not have been secured by substituting simple engines, and

making the other conditions the same. The matter has never been thoroughly settled by experiment, which would seem to be the most natural method of deciding such a controversy; but the theory of the subject has been pretty fully set forth, with considerable experimental data, in the discussion that has been conducted for several years in the columns of *Engineering* (which may be called pro-

1404.

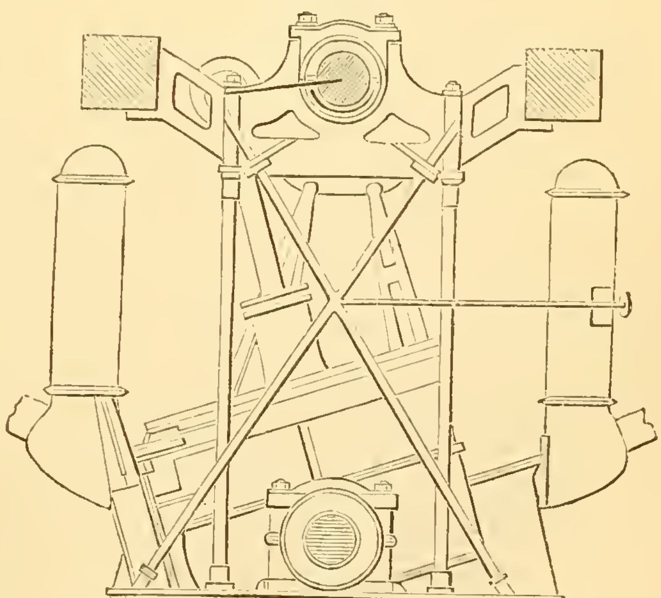


1405.




compound) and *The Engineer* (anti-compound). The compound engine affords one advantage, when it is desired to use two engines at a high grade of expansion. It will be seen by reference to diagram 7 in the article CRANK, that for a pair of simple engines coupled at right angles, the most even distribution of pressure on the crank is effected when the cut-off takes place at half stroke. By the use of a compound engine, however, with the large and small cylinders connected at right angles, a high grade of expansion can be used, with an approximately even distribution of pressure on the crank. Of course, the same thing can be effected with the simple engine by the use of heavy reciprocating parts and high piston-speed, or by having several cylinders; but in general, the result can probably be produced more simply by compounding the engine. Whether any decided gain results from the use of a very high grade of expansion is questionable; so that the opponents of the compound engine seem to have some reason for their opinions. There are some special advantages in the compound engine, besides the even distribution of pressure already referred to; one of the most important being that the cylinder in which steam of high pressure is used is not directly exposed to the refrigerating influence of the condenser. Another practical advantage seems to be, that while with a simple engine the engineer frequently finds it easier to lower the initial pressure and increase the period of admission, thus rendering the engine less economical than if it were worked at the proper steam-pressure and cut-off, with the compound engine the pressure cannot be lowered except at the expense of the power produced. This point was referred to by Mr. Bramwell in a valuable paper on marine engines, published in the "Transactions of the Institution of Mechanical Engineers," 1872; and it is more fully discussed in an article by C. E. Emery on "Compound and Non-compound Engines, Steam-Jackets, etc.," published in the "Transactions of the American Society of Civil Engineers" for February, 1875. The last paper referred to contains records of experiments with compound and simple engines, which,

1406.



with other experiments by the same engineer published in a pamphlet entitled "Report of the Trial of the Steam Machinery of the United States Revenue Steamer Gallatin," etc., constitute the principal comparative experiments relating to this subject that have been published. Although these experiments are hardly thorough enough to settle the question definitely—being made with engines of only moderate size, most of the trials being of very limited duration, and the conditions not being such as to make them strictly comparative—they are of exceeding interest and value. A summary of the experiments is given in the following table and in that on page 659.

*Principal Dimensions of Engines.*

| DETAILS. | Rush. | Bache. | Gallatin. | Dexter. | Dallas. |
|---|---|---|---|---|---|
| Number of cylinders | 2 | 2 | 1 | 1 | 1 |
| Diameter of cylinders, inches | 24 and 38 | 16 and 25 | 34.1 | 26 | 36 |
| Length of stroke, inches | 27 | 24 | 30 | 36 | 30 |
| Area of cylinder ports, square inches | 31.5 and 64.1 | 13.5 and 27 | 57.4 | 32 | 77.1 |
| Clearance in per cent. of piston displacement | 7.89 and 5.85 | 4.86 and 4.05 | 6.59 | 5.37 | 8.02 |

In experiments 3–10, 12, and 14, the intermediate chamber was drained during the runs; and in experiment 22, the steam-chest was drained. The link was hauled up in experiments 27, 33, and 37; and in the two last-named experiments the independent cut-off was not in use. In experiments 29 and 39, the steam-jacket was supplied direct from the boiler; and in numbers 51 and 55, the jacket was supplied with steam at a pressure of 70 lbs. above the atmosphere. In experiments 41, 46, 48, and 49, the steam was condensed without vacuum. For those who wish to consult the original tables, we have inserted a column of corresponding numbers.

It will be seen that, with the exception of a single run of the Rush, the record given in the table is scarcely conclusive in regard to the great economy of the compound engine. With respect to the value of the steam-jacket, these experiments are also somewhat contradictory. Some very thorough experiments on this subject are described by Chief Engineer B. F. Isherwood, in the "Annual Report of the Chief of the Bureau of Steam Engineering, U. S. Navy Department," for 1875. The engine used in the experiments had a cylinder 10 inches in diameter and 24 inches stroke of piston. The cylinder, piston, and piston-rod were steam-jacketed, and the different portions of the jacket, or the whole, could be shut off at pleasure. The table appended contains a summary of the experiments made with this engine:

*Summary of Experiments on Waterman's Engine.*

| DESIGNATION OF EXPERIMENT. | Ratio of Expansion. | Revolutions per Minute. | STEAM-PRESSURE IN CYLINDER, IN POUNDS PER SQUARE INCH. Initial above Zero. | STEAM-PRESSURE IN CYLINDER, IN POUNDS PER SQUARE INCH. Mean Net. | Net Horse-power. | Water per net Horse-power per Hour. | REMARKS. |
|---|---|---|---|---|---|---|---|
| A | 3.62 | 43.1 | 50.6 | 21.25 | 8.66 | 47.75 | No steam in the jackets. |
| B | 1.93 | 43.1 | 37.7 | 21.83 | 8.9 | 54.19 | |
| C | 1.47 | 43.1 | 33.3 | 20.75 | 8.46 | 58.62 | |
| D | 1.11 | 43.1 | 30.5 | 20.87 | 8.51 | 64.04 | |
| E | 3.62 | 61.4 | 21 | 4.28 | 2.48 | 129.56 | |
| F | 1.11 | 61.5 | 15.2 | 6.15 | 3.51 | 117.02 | |
| G | 3.62 | 43.2 | 50.2 | 21.77 | 8.88 | 35.25 | Steam of boiler pressure in the jackets. |
| H | 3.08 | 43.1 | 44.3 | 21.82 | 8.9 | 36.2 | |
| I | 1.93 | 43.2 | 34.4 | 20.87 | 8.52 | 39.03 | |
| J | 1.93 | 43.1 | 36.1 | 22.07 | 8.99 | 38.27 | |
| K | 1.32 | 43.1 | 31.4 | 21.18 | 8.63 | 43.75 | |
| L | 1.11 | 43.2 | 28.6 | 20.34 | 8.64 | 49.52 | |
| M | 1.11 | 61.4 | 13.6 | 5.92 | 3.43 | 80.97 | |
| N | 3.08 | 43.2 | 47.1 | 20.82 | 8.49 | 33.28 | Steam in jackets at pressure of 129 lbs. above zero. |
| O | 1.93 | 43.1 | 34.4 | 20.39 | 8.3 | 36.49 | " " " 133 " " " |
| P | 1.32 | 43 | 31.9 | 21.73 | 8.43 | 40.84 | " " " 142 " " " |
| Q | 3.62 | 43.1 | 47.6 | 20.58 | 8.39 | 40.56 | Steam of boiler pressure in jackets—jackets not drained. |
| R | 1.93 | 43.1 | 36 | 22.31 | 9.09 | 38.56 | Steam of boiler pressure in jackets, except upper cylinder-head jacket. |
| S | 1.32 | 43.1 | 33.2 | 21.98 | 8.95 | 48.57 | Steam of boiler pressure in jackets, except lower cylinder-head jacket. |
| T | 3.62 | 43.1 | 46 | 20.23 | 8.24 | 39.17 | Steam of boiler pressure in jackets, except piston and piston-rod jacket. |

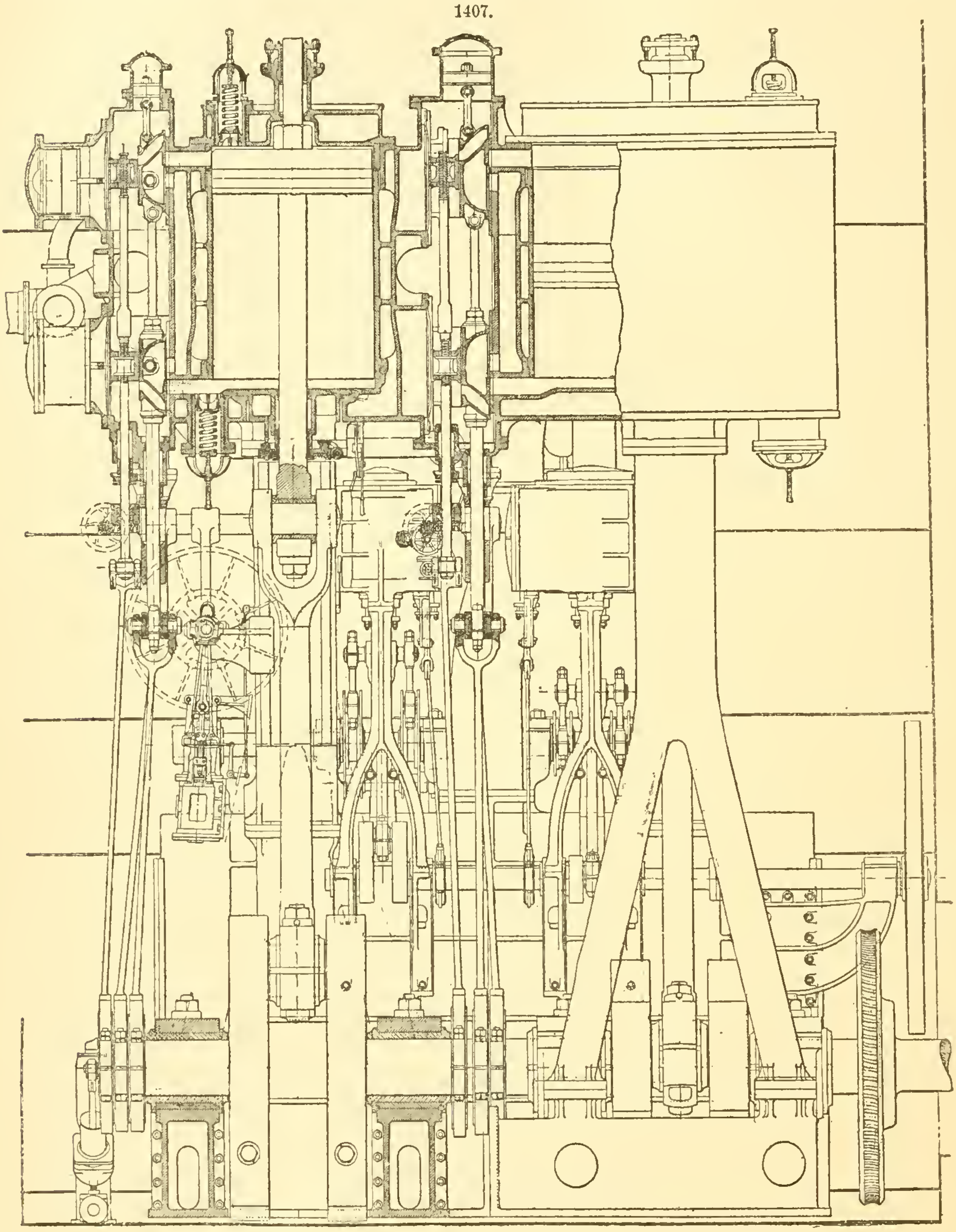
Fig. 1407, which is a sectional elevation of the engines of the San Francisco, is a good example of the modern compound engine used in ocean steamers. The San Francisco is 352 feet long over all, with a beam of 40 feet, and a depth of hold of 28 feet 10 inches. The steam-cylinders have diameters of 51 and 88 inches, with a stroke of 5 feet. They are steam-jacketed on the sides and heads. The main valves, each worked by two eccentrics, cut off the steam at two-thirds of the stroke, and a cut-off valve, consisting of two plates adjustable by right- and left-hand screws, works on the back of each main valve, changing the point of cut-off, as desired, from one-tenth to two-thirds of the

*Summary of Experiments with Engines of the United States Revenue Steamers Rush, Bache, Gallatin, Dexter, and Dallas,* 1874, 1875.

| NUMBER FOR REFERENCE. | Number in original Tables. | NAME. | Compound or Simple. | Steam-Jacket. | Duration of Experiment, in Hours. | Initial Pressure, in Pounds per Square Inch above Zero. | Ratio of Expansion. | Revolutions per Minute. | HORSE-POWER. Total. | HORSE-POWER. Indicated. | POUNDS OF WATER PER HOUR. Per Total Horse-power. | POUNDS OF WATER PER HOUR. Per Indicated Horse-power. | NUMBER FOR REFERENCE. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 1 | Rush. | Compound. | In use. | 55 | 82.3 | 6.22 | 70.8 | 304.3 | 266.5 | 16.1 | 18.4 | 1 |
| 2 | 2 | | " | " | 6 | 50.2 | 4.03 | 55.5 | 197.8 | 168.7 | 18.8 | 22.1 | 2 |
| 3 | 6 | | Compound. | In use. | 1.93 | 93.5 | 6.98 | 53.2 | ..... | 99.2 | .... | 20.3 | 3 |
| 4 | 7 | | " | " | 1.98 | 90.3 | 5.73 | 56.3 | ..... | 110.5 | .... | 20.4 | 4 |
| 5 | 5 | | " | " | 2.07 | 92 | 9.19 | 48.2 | ..... | 77.5 | .... | 20.7 | 5 |
| 6 | 10 | | " | " | 2 | 87.3 | 4.24 | 60.6 | ..... | 134.5 | .... | 21.2 | 6 |
| 7 | 8 | | " | " | 7.07 | 90 | 5.71 | 55.6 | ..... | 106. | .... | 22 | 7 |
| 8 | 9 | | " | " | 15.23 | 88.8 | 5.1 | 53.6 | ..... | 102.3 | .... | 22.4 | 8 |
| 9 | 2 | | " | Not in use. | 2.13 | 87.7 | 5.63 | 49.3 | ..... | 85.8 | .... | 23.2 | 9 |
| 10 | 3 | Bache. | " | " " | 2.07 | 91.1 | 6.66 | 47.7 | ..... | 77.1 | .... | 23 | 10 |
| 11 | 16 | | Simple. | In use. | 2.12 | 90.7 | 5.11 | 53.8 | ..... | 116 | .... | 23.2 | 11 |
| 12 | 1 | | Compound. | Not in use. | 1.83 | 89.7 | 9.15 | 42.6 | ..... | 55.9 | .... | 23.8 | 12 |
| 13 | 15 | | Simple. | In use. | 1.68 | 90.1 | 8.57 | 46.2 | ..... | 74.6 | .... | 24.1 | 13 |
| 14 | 4 | | Compound. | " | 1.73 | 90.6 | 16.85 | 38.9 | ..... | 46.4 | .... | 25.1 | 14 |
| 15 | 13 | | Simple. | Not in use. | 2.05 | 87.4 | 5.32 | 47.1 | ..... | 89.1 | .... | 26.2 | 15 |
| 16 | 14 | | " | In use. | 2.1 | 88.8 | 12.62 | 39.9 | ..... | 54.8 | .... | 27.1 | 16 |
| 17 | 12 | | " | Not in use. | 1.98 | 90.7 | 7.62 | 44.9 | ..... | 71.8 | .... | 29.6 | 17 |
| 18 | 17 | | " | In use. | 1.88 | 41.5 | 2.18 | 45.3 | ..... | 66.7 | .... | 34 | 18 |
| 19 | 11 | | " | Not in use. | 1.8 | 88.9 | 11.82 | 37.3 | ..... | 47.2 | .... | 35.1 | 19 |
| 20 | 39 | | | In use. | 2.22 | 85 | 7.31 | 51.1 | 222.2 | 197 | 18.2 | 20.5 | 20 |
| 21 | 43 | | | " | 1.93 | 80.7 | 4.19 | 68.7 | 389.3 | 348 | 19·2 | 21.5 | 21 |
| 22 | 29 | | | Not in use. | 2.5 | 82.4 | 4.91 | 60.2 | 316.8 | 289.2 | 19.8 | 21.7 | 22 |
| 23 | 36 | | | " " | 2.02 | 81.7 | 4.94 | 59.9 | 311.4 | 279.6 | 19.7 | 21.9 | 23 |
| 24 | 38 | | | In use. | 23.98 | 77.8 | 4.5 | 61.5 | 315.3 | 281.6 | 19.7 | 22 | 24 |
| 25 | 16 | | | " | 2.2 | 54.6 | 4.82 | 45.9 | 158.3 | 136.4 | 19.3 | 22.4 | 25 |
| 26 | 14 | | | " | 2.02 | 58 | 6.08 | 44.3 | 143.7 | 121.1 | 19.3 | 22.9 | 26 |
| 27 | 27 | | | " | 2.07 | 70.2 | 3.45 | 58.6 | 298.3 | 258.5 | 19.9 | 23 | 27 |
| 28 | 18 | | | " | 2.03 | 54.7 | 3.71 | 49.2 | 191.6 | 166.2 | 20.1 | 23.2 | 28 |
| 29 | 31 | | | " | 1.87 | 82.6 | 4.87 | 58.5 | 289.3 | 255.3 | 20.7 | 23.5 | 29 |
| 30 | 35 | | | Not in use. | 2.05 | 80.8 | 5.63 | 56 | 267.3 | 231.4 | 20.6 | 23.8 | 30 |
| 31 | 9 | | | " " | 2.05 | 55.8 | 3.73 | 50.8 | 204.7 | 182.2 | 21.4 | 24 | 31 |
| 32 | 15 | | | In use. | 2.05 | 53.9 | 5.07 | 46.1 | 158.5 | 137.5 | 20.8 | 24 | 32 |
| 33 | 28 | | | " | 1.95 | 63.6 | 2.37 | 60.9 | 334.3 | 284.2 | 20.6 | 24.2 | 33 |
| 34 | 33 | | | Not in use. | 23.95 | 76.2 | 4.46 | 60.5 | 304.1 | 268.6 | 21.5 | 24.4 | 34 |
| 35 | 11 | | | " " | 2.32 | 52.3 | 2.72 | 56 | 265.6 | 236.9 | 21.8 | 24.5 | 35 |
| 36 | 17 | | | In use. | 2.22 | 54.7 | 4.49 | 50.3 | 189.7 | 163.3 | 21.4 | 24.8 | 36 |
| 37 | 26 | Gallatin. | Simple. | Not in use. | 1.92 | 66.9 | 2.47 | 62 | 354.5 | 297.8 | 21.2 | 25.2 | 37 |
| 38 | 20 | | | In use. | 2.08 | 49.3 | 2.4 | 54.5 | 234.5 | 213 | 23 | 25.3 | 38 |
| 89 | 32 | | | " | 2.03 | 78.1 | 3.83 | 61.6 | 321.4 | 282.5 | 22.3 | 25.3 | 39 |
| 40 | 19 | | | " | 3.75 | 52.4 | 3.32 | 51.2 | 217.9 | 185.2 | 21.9 | 25.7 | 40 |
| 41 | 24 | | | " | 2.05 | 82.6 | 4.07 | 49.5 | 290.6 | 189.6 | 16.9 | 25.9 | 41 |
| 42 | 7 | | | Not in use. | 1.77 | 56.3 | 5.92 | 43 | 142.5 | 122.8 | 22.4 | 26 | 42 |
| 43 | 10 | | | " " | 2.1 | 51.8 | 3.16 | 50.1 | 213 | 182.4 | 22.5 | 26.3 | 43 |
| 44 | 21 | | | In use. | 2.3 | 50.4 | 2.21 | 58.2 | 291 | 255 | 23.2 | 26.5 | 44 |
| 45 | 8 | | | Not in use. | 1.98 | 52.8 | 5.21 | 44.2 | 147.9 | 127.2 | 23 | 26.7 | 45 |
| 46 | 25 | | | In use. | 2.12 | 78.8 | 3.52 | 43.8 | 319.7 | 212.2 | 18.1 | 27.3 | 46 |
| 47 | 12 | | | Not in use. | 2.17 | 50.3 | 2.23 | 55.8 | 278.7 | 236.5 | 23.8 | 28.1 | 47 |
| 48 | 23 | | | " " | 2.22 | 79.1 | 3.48 | 51.7 | 309.2 | 204.8 | 19.4 | 29.4 | 48 |
| 49 | 22 | | | " " | 2.2 | 83.7 | 4.37 | 46.7 | 264.9 | 169.6 | 19.2 | 30 | 49 |
| 50 | 3 | | | In use. | 2.1 | 26.3 | 2 | 41.3 | 115.7 | 95.3 | 27.4 | 33.3 | 50 |
| 51 | 6 | | | " | 2.2 | 25 | 1.54 | 42.3 | 123.2 | 102.9 | 29.1 | 34.9 | 51 |
| 52 | 4 | | | " | 2.13 | 24.1 | 1.49 | 42.5 | 121.2 | 97.9 | 30.2 | 37.4 | 52 |
| 53 | 1 | | | Not in use. | 1.92 | 25.3 | 2.02 | 40.1 | 107.2 | 87 | 32.8 | 40.4 | 53 |
| 54 | 2 | | | " " | 2.25 | 28.7 | 1.51 | 40.9 | 121.4 | 90.2 | 35.7 | 44.2 | 54 |
| 55 | 5 | | | In use. | 2.22 | 23.9 | 1.8 | 41.1 | 106.7 | 89.7 | 28.6 | 34.1 | 55 |
| 56 | 3 | | | | 2.92 | 80.4 | 4.46 | 56.5 | 204.5 | 185.9 | 21.7 | 23.9 | 56 |
| 57 | 5 | | | | 34.5 | 79.2 | 3.49 | 61.1 | 240.3 | 219 | 21.8 | 23.9 | 57 |
| 58 | 4 | | | | 1.42 | 79.3 | 3.67 | 64.3 | 251 | 228.1 | 21.9 | 24.1 | 58 |
| 59 | 6 | Dexter. | Simple. | Not jacketed. | 0.65 | 77 | 2.72 | 72.8 | 329 | 292.4 | 21.6 | 24.3 | 59 |
| 60 | 7 | | | | 1.32 | 52.3 | 3.34 | 50.8 | 139.6 | 124.3 | 25.6 | 28.8 | 60 |
| 61 | 8 | | | | 1.2 | 51.4 | 2.42 | 55.3 | 181 | 161.8 | 25.9 | 28.9 | 61 |
| 62 | 9 | | | | 0.92 | 53.6 | 2.08 | 70.7 | 221.2 | 196.2 | 28.2 | 31.8 | 62 |
| 63 | 10 | | | | 1.52 | 46.9 | 5.07 | 48.7 | 160.1 | 138 | 23 | 26.7 | 63 |
| 64 | 12 | | | | 31 | 46.6 | 3.13 | 61.5 | 258.2 | 221.4 | 23.1 | 26.9 | 64 |
| 65 | 11 | Dallas. | Simple. | Not jacketed. | 1.55 | 47 | 3.89 | 56.9 | 216.1 | 186.8 | 23.3 | 27 | 65 |
| 66 | 13 | | | | 1.6 | 45.9 | 2.94 | 64.5 | 283.4 | 242.8 | 24.8 | 28.9 | 66 |
| 67 | 14 | | | | 1.53 | 39.4 | 2.32 | 63.5 | 274 | 234.3 | 26.5 | 31 | 67 |

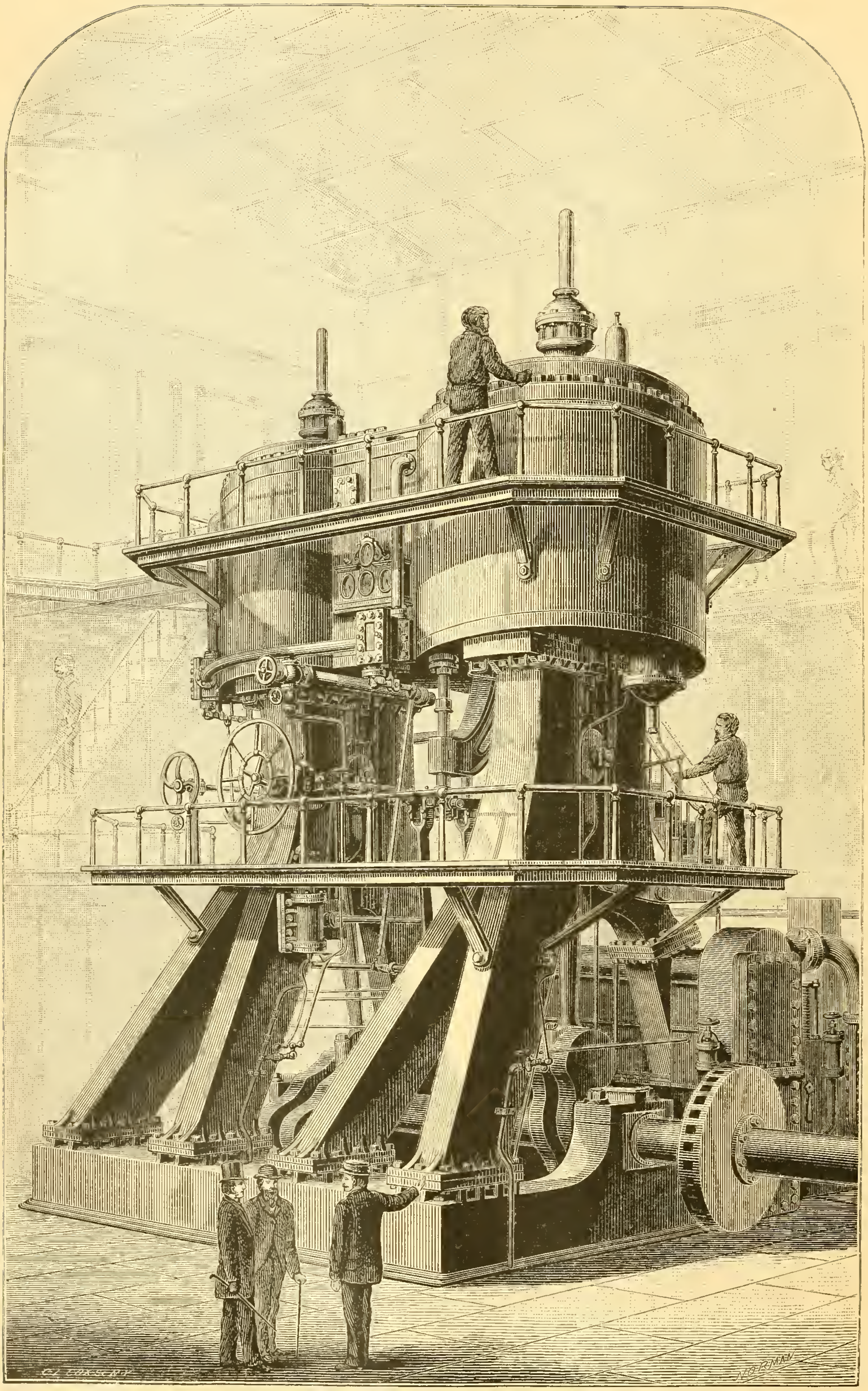
stroke. The valves are balanced by pistons, as shown. The surface-condenser contains 2,380 tinned brass tubes, each having a diameter of three-fourths of an inch and a length of $13\frac{3}{4}$ feet, thus giving 6,425 square feet of condensing surface. There are two single-acting air-pumps, each 24 inches in diameter and 24 inches stroke; also two double-acting circulating pumps, each $14\frac{1}{2}$ by 24 inches.

1407.



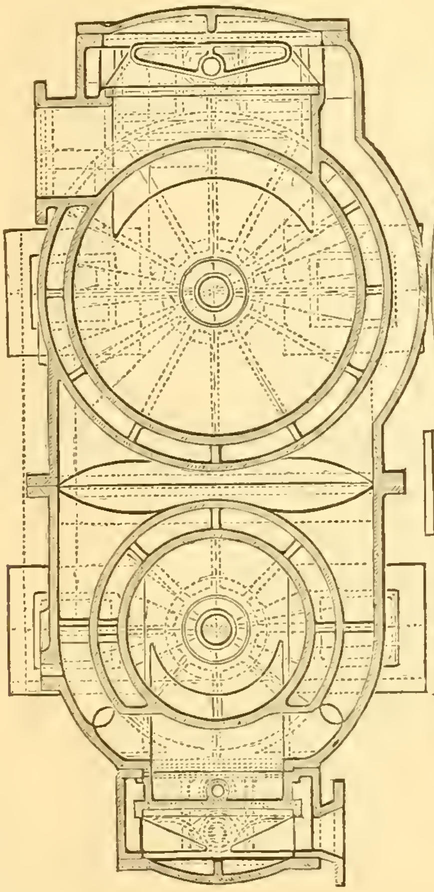
The air and circulating pumps are worked by independent engines. We give in a full-page engraving a perspective view of the engines, quite similar in design, of the City of Savannah.

The engines of the United States revenue steamer Rush are illustrated in the accompanying figures. Fig. 1408 is an elevation; Figs. 1409 and 1410, sectional views of the cylinders; Fig. 1411, vertical cross-section of one of the pistons; Fig. 1412, different views of the auxiliary starting-valve; Figs. 1413 to 1416, air, feed, and bilge pumps; and Figs. 1417 and 1418, surface-condenser. The following are the principal dimensions: *Hull*—Length over all, 140 feet; length between perpendiculars at water-line, 129 feet 6 inches; breadth of beam, 23 feet; depth of hold, 10 feet; load draught of water aft, 8 feet 10 inches; displacement to load line, 370 tons. *Engines*—Diameter of high-pressure cylinder, 24 inches; diameter of low-pressure cylinder, 38 inches; stroke of pistons, 27 inches; diameter of air-pump, 19 inches; number of tubes in condenser, 781; diameter of tubes, 0.625 inch; length of tubes, 7 feet; condensing surface, 895 square feet.

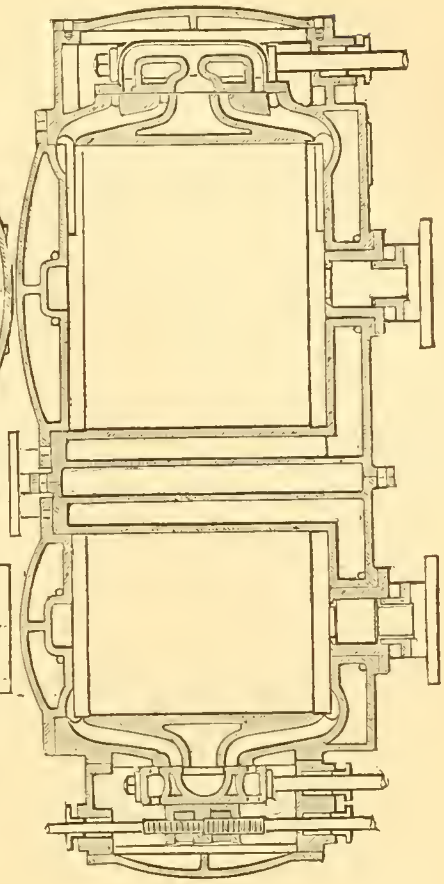


AMERICAN MARINE STEAM-ENGINE.

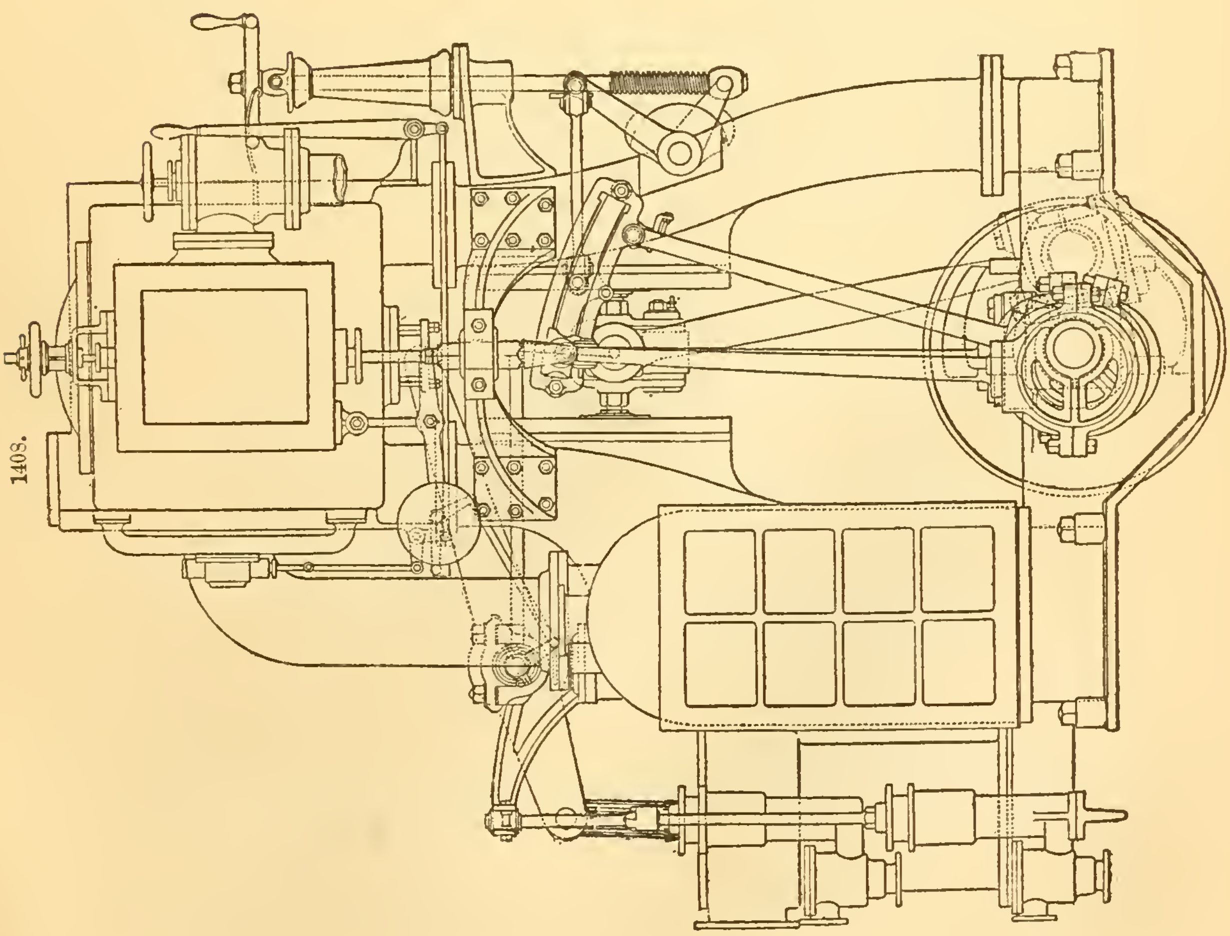
1409.



1410.

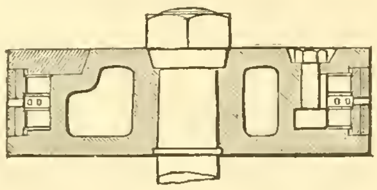


1408.

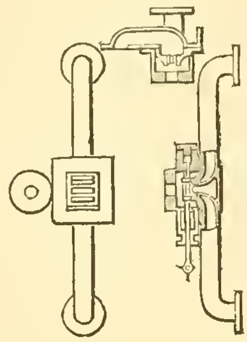


IV. Sea-going Steamers.—One of the finest examples of American practice in the construction of sea-going steamers is found in the City of Peking, built for the Pacific Mail Company. The hull is

1411.

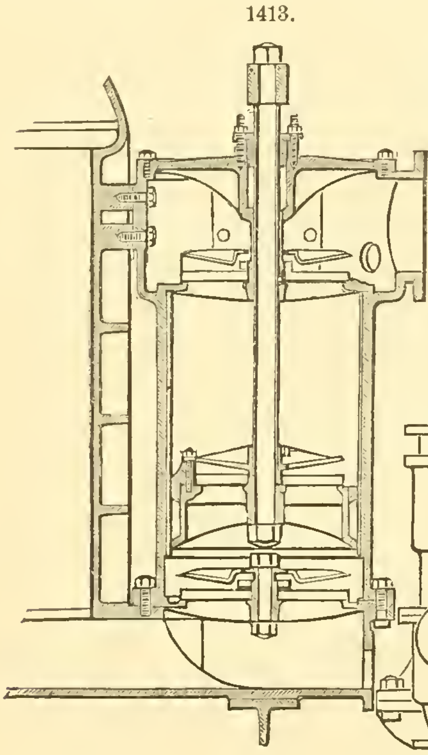


1412.

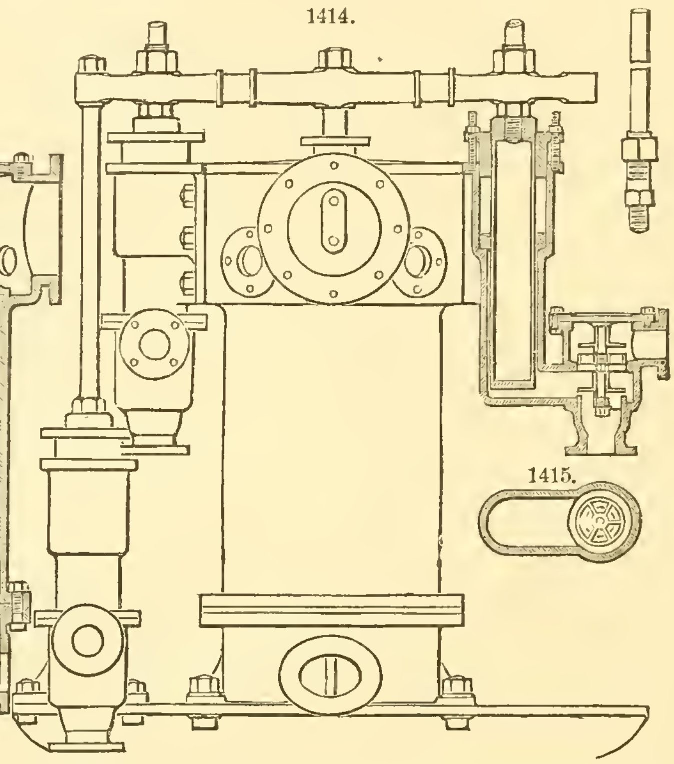


423 feet long, of 48 feet beam, and $38\frac{1}{2}$ feet deep. Accommodations are furnished for 150 cabin and 1,800 steerage passengers, and the coal-bunkers stow 1,500 tons of coal. The iron plates of

1413.



1414.

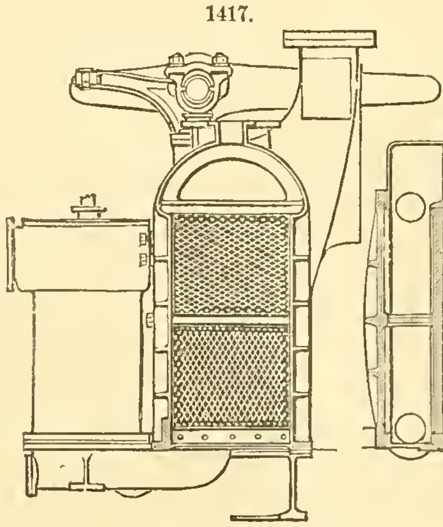


1416.

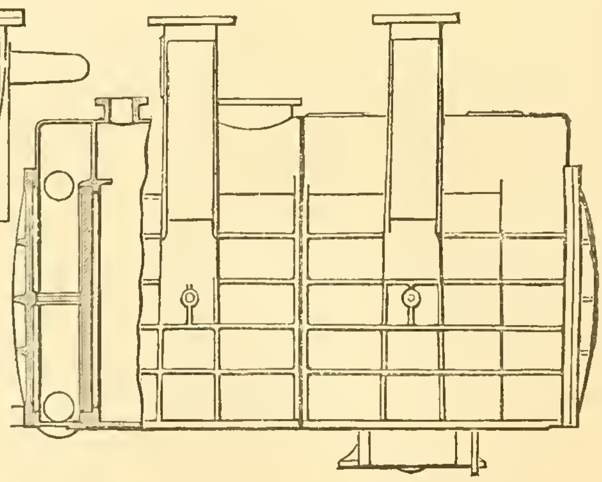
1415.

which the sides and bottom are made are from $\frac{1}{16}$ to one inch in thickness. The weight of iron used in construction was about 5,500,000 pounds. The machinery weighs nearly 2,000,000 pounds, with

1417.



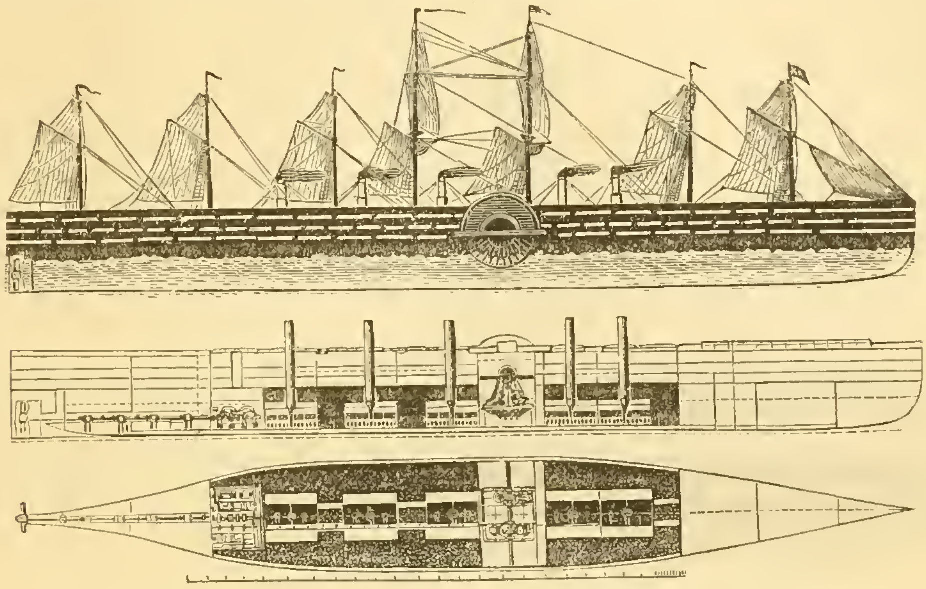
1418.



spare gear and accessory apparatus. The engines are compound, with two steam-cylinders of 51 inches and two of 88 inches diameter, and a stroke of piston of $4\frac{1}{2}$ feet. The condensing water is sent

through the surface-condensers by circulating pumps driven by their own engines. Ten boilers furnish steam to these engines, each having a diameter of 13 feet, a length of 13½ feet, and a thickness of shell of thirteen-sixteenths of an inch. Each has three furnaces, and contains 204 tubes of an outside diameter of 3¼ inches. All together, they have 520 square feet of grate surface and 17,000 square feet of heating surface. The area of cooling surface in the condensers is 10,000 square feet. The machinery is proportioned to develop 4,000 horse-power at 55 revolutions per minute, with steam of 60 lbs. pressure, expanding down to 10 lbs. before being exhausted into the condenser. The screw is four-bladed, 20¼ feet in diameter, and has a pitch of 30 feet. This

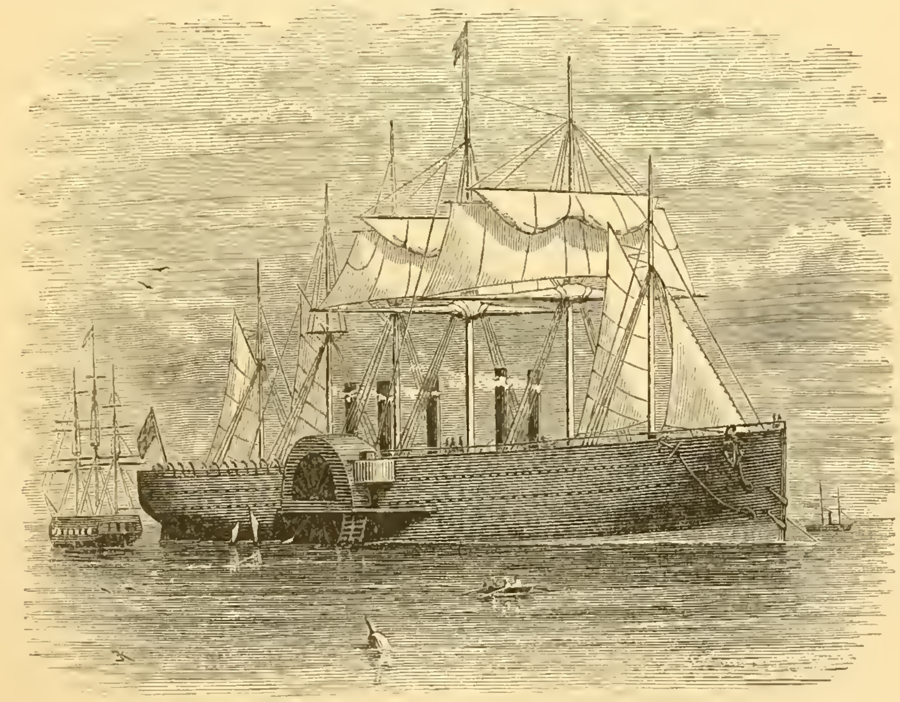
1419.



steamer has made 15.8 knots per hour, equal to 19 statute miles, and burns from 40 to 80 tons of coal per day, according to the speed and the state of the weather.

The largest vessel of any class yet constructed is the Great Eastern, Figs. 1419 and 1420 (which engravings, together with others of vessels here given, are extracted from Thurston's "Growth of the Steam-Engine," New York, 1878), begun in 1854 and completed in 1859, by J. Scott Russell, on the

1420.

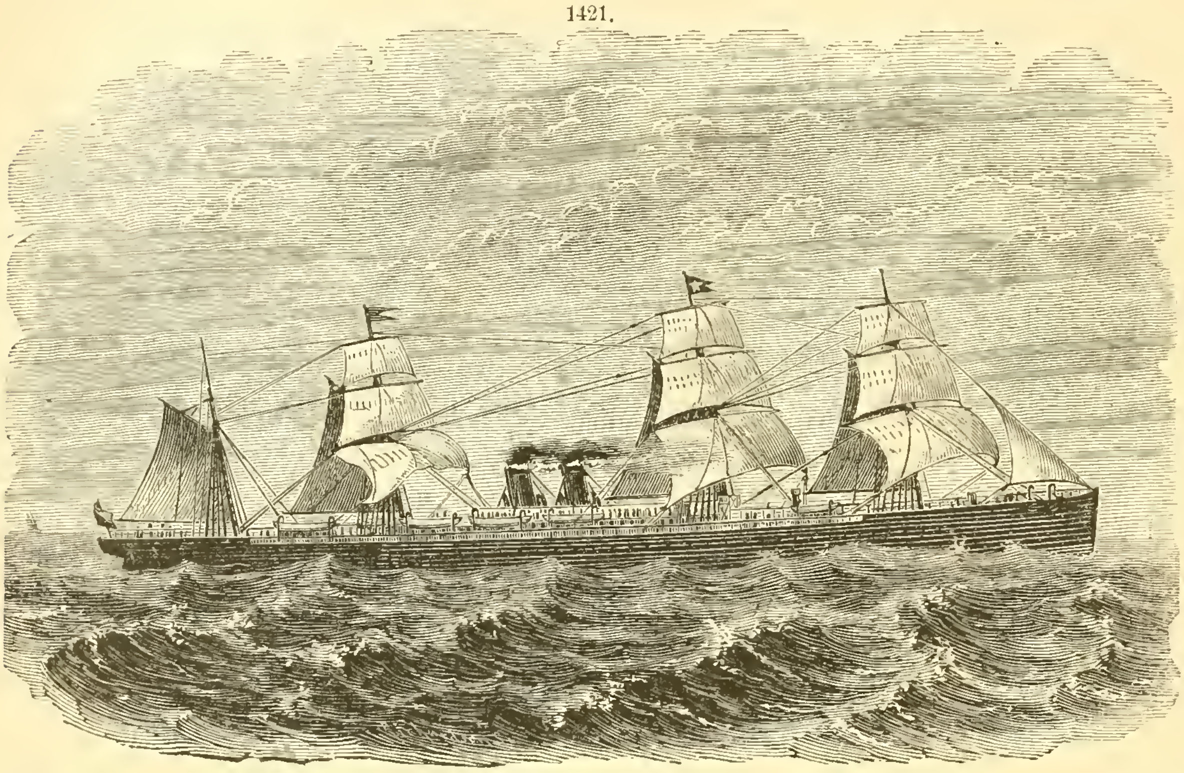


Thames, England. This ship is 680 feet long, 83 feet wide, 58 feet deep, 28 feet draught, and of 24,000 tons measurement. There are four paddle- and four screw-engines, the former having steam-cylinders 74 inches in diameter, with 14 feet stroke, the latter 84 inches in diameter and 4 feet stroke. The paddle-wheels are 56 feet in diameter, the screw 24 feet. The steam-boilers supplying the paddle-engines have 44,000 square feet (more than an acre) of heating surface. The boilers supplying the screw-engines are still larger. At 30 feet draught, this great vessel displaces 27,000 tons. The engines were designed to develop 10,000 horse-power, driving the ship at the rate of 16½ statute miles an hour.

Details of modern iron-clad war-vessels will be found under ARMOR.

The most successful steam sea-going vessels in general use are the screw steamers of the Transatlantic lines. These, as will be seen from the following tables, are from 350 to 450 feet in length, and are generally propelled at from 12 to 15 knots per hour by engines of from 3,000 to 4,000

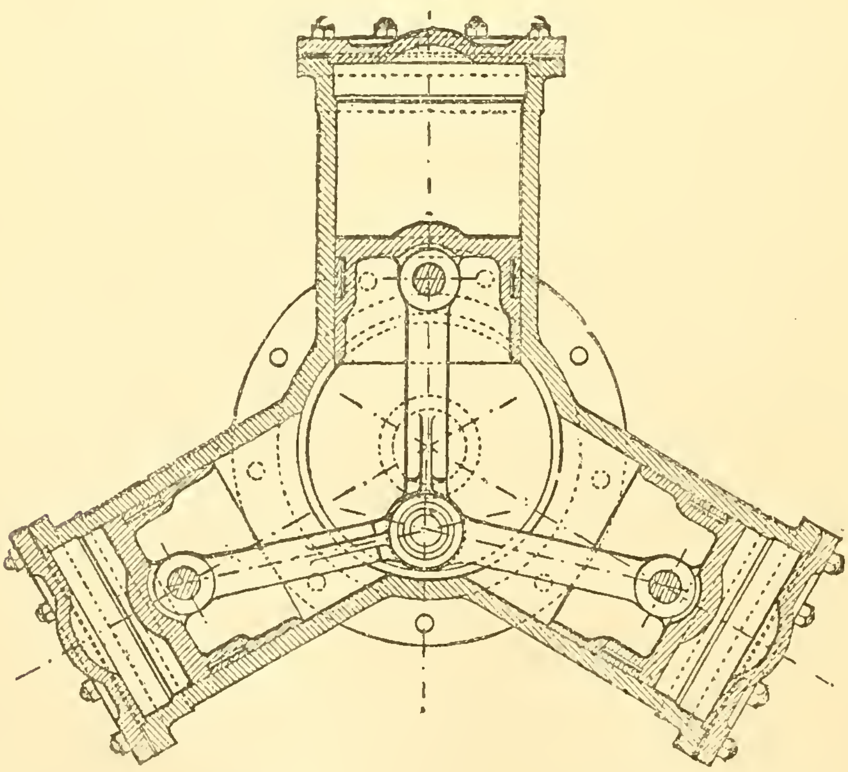
1421.



horse-power, consuming from 70 to 100 tons of coal per day, and crossing the Atlantic in from 8 to 10 days. One of the largest of these vessels is represented in Fig. 1421.

STEAM-LAUNCH, YACHT, AND TUG-BOAT ENGINES.—*Brotherhood and Hardingham's Three-Cylinder Engine*, represented in Fig. 1422, has been successfully applied in a number of instances to small steam-yachts. It is also said to be well adapted to driving circulating-pumps for surface-condensers. The engine is thus described in *Engineering* for October 3, 1873: "Three cylinders are arranged at

1422.

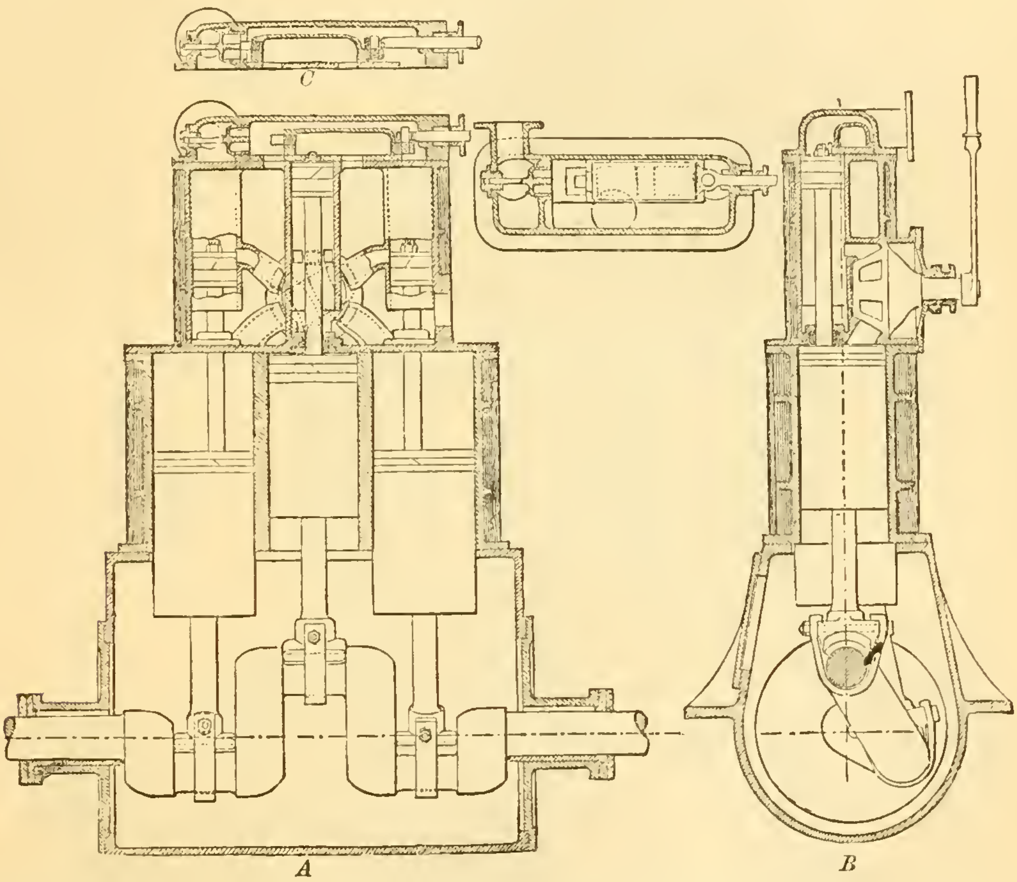


angles of 120° with each other, around a central chamber, with which they communicate, the whole being cast in one piece. Each cylinder has its own piston and connecting-rod, the three rods taking on to one common crank. The crank-pin, after passing through the connecting-rod eyes, is prolonged, and fits into a hole in a rotary slide-valve, which it thus actuates. The valve has a steam and an exhaust port, which are alternately placed in communication with the passage belonging to

each cylinder. In working this engine, steam is admitted to the central chamber, and exerts an equal pressure on the inner sides of the three pistons. Thus far the machine would be *in equilibrio.* But steam now passes through the slide-valve to the outer side of one piston, thus throwing that piston into equilibrium, but the three pistons collectively out of equilibrium. A rotary motion of the crank and slide-valve ensues, and the other pistons are alternately operated upon in a similar manner, the constant effective area for pressure being a piston and a half."

*Willan's Three-Cylinder Engine.*—This engine has been fitted to several fast steam-launches in the British navy, and under circumstances of actual trial has achieved notably successful results. Its construction, so arranged that it can be worked compound or non-compound at pleasure, is represented in Fig. 1423. When working compound, one cylinder of course acts as the high-pressure and the other two conjointly as the low-pressure cylinders. Referring to *A* and *B*, it will be seen that in the chamber above the valve-cylinders there is fitted a long cupped slide-valve movable by a rod and hand-lever, one end of this valve being furnished with a projection which, when the valve is put into the position shown in *C*, comes into contact with and opens an ordinary mitre-valve fitted to a hole in the partition which divides the chamber into two parts. When the valves are in the position shown in *A*, the steam is admitted from the boiler to the left-hand compartment of the chamber only, and it can thus gain access to but one of the valve-cylinders, namely, that on the left. When the engine is in the gear shown, the left-hand valve controls the admission of steam to and its release

1423.




from the middle cylinder, and in *A* this cylinder is represented just taking steam, the piston being at the top of its stroke. On its discharge from the middle cylinder the steam first passes into the space surrounding the left-hand valve-cylinder (which space acts as a receiver), and then up through the port on the left, shown in *A* to be uncovered by the slide-valve already mentioned. In this way the steam reaches the top chamber, and from this chamber it is admitted to the two other valve-cylinders, and distributed by their valves as if it were live steam from the boiler. Finally, after acting on the two low-pressure cylinders, it is discharged into the space between the centre and right-hand valve-cylinders, with which space the exhaust-pipe communicates. When working as a simple engine, the slide-valve is pushed over into the position shown in *C*, in which position it covers both the ports in the bottom of the chamber in which it works, and places the space between the left-hand and centre valve-cylinders in free communication with that between the centre and right-hand valve-cylinders, and hence also with the exhaust-pipe. At the same time the movement of the slide-valve into the position shown in *C* opens the mitre-valve already referred to, and admits live steam into both compartments of the top chamber, and thus each valve-cylinder takes its supply of steam direct from the boiler. It will be seen from an examination of the arrangement that when compounded the engine can be run in one direction only, but when working non-compound it can of course be reversed by the cone-valve at the side. A launch 40 feet long, with 9 feet beam and a draught of 3 feet 6 inches, has been driven at a speed of 7½ knots by one of these engines, with a consumption of 36 lbs. of coal per hour. The indicated power required to drive the boat at the 7½ knot speed was not ascertained, but a speed of 8¾ knots was obtained with the same boat with power of 40-horse indicated. For reports of trial of this engine in steam-launches, see *Engineering*, xxv., 407.

*High-Pressure Tugboat Engine.*—Fig. 1424 represents a single-cylinder, high-pressure, surface-condensing engine built by Messrs. William Cramp & Sons of Philadelphia, for tugboat use. As shown in the engraving, the point of cut-off is controlled by altering the stroke of the expansion-valve. It will be seen that the lower end of the expansion-valve spindle terminates in a cross-head working in guides. On the side of the cross-head is a pin on which is placed a link which descends as far as an oscillating segmental arm attached at one end to one of the main pillars forming the framing of the engine. To this arm, which is graduated, is attached the upper end of the link, to which motion is given by a crank on the main shaft, as shown. The lower end of the link, descending from the cross-head of the expansion-valve spindle, slides upon the graduated arm, and may be locked in any desired position by means of the screw and handle shown; and by sliding it to and fro, any desired degree of expansion may be obtained. The reversing gear consists of a hand-wheel carrying a pinion on its shaft, which gears into a segment with internal teeth, and throws the lever attached to the link to and fro. The air-pump is worked in the ordinary way by back-levers connected with the cross-head, which latter works on a slipper-guide upon the main frame. The diameter of the cylinder is 20 inches and the length of stroke 22 inches. With 59 lbs. initial pressure in the cylinder and a speed of 100 revolutions per minute, an indicated horse-power of 196 was developed on trial.

1424.

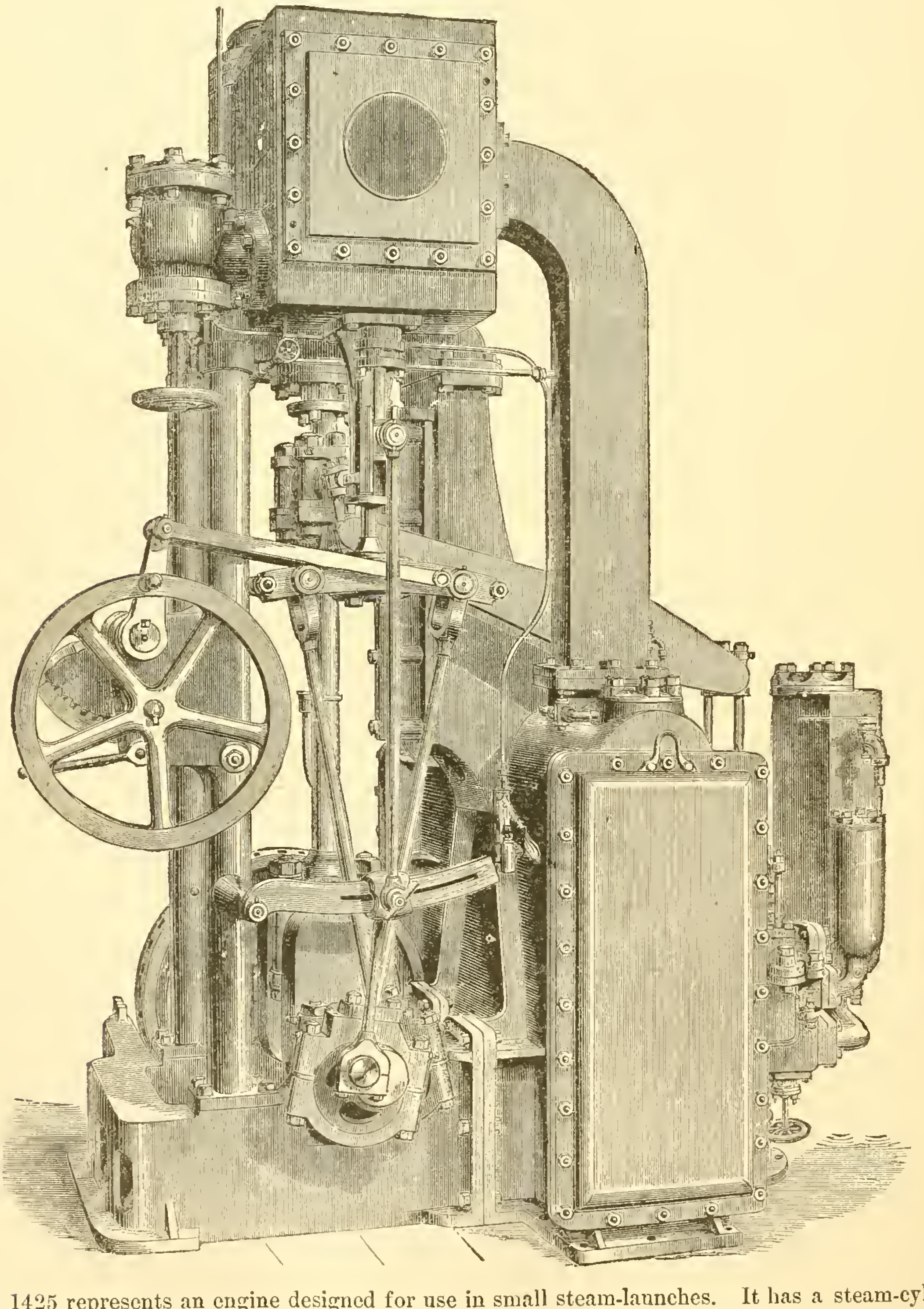
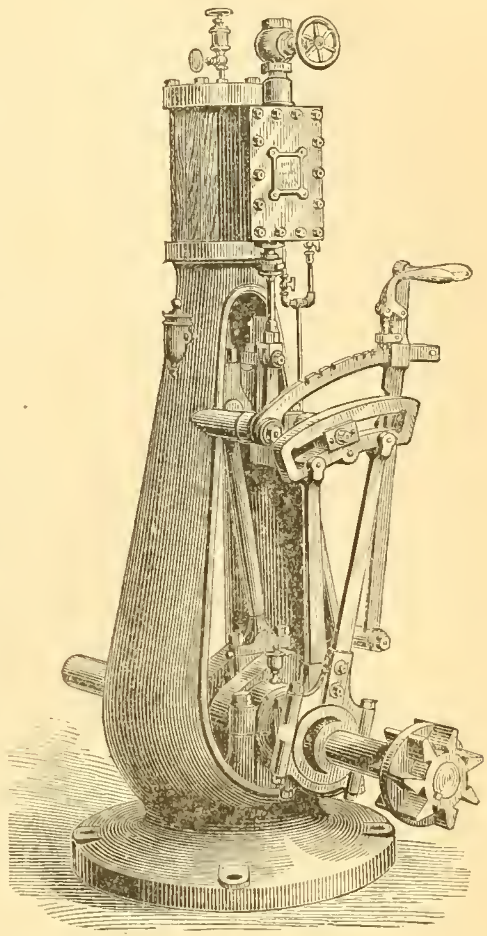


Fig. 1425 represents an engine designed for use in small steam-launches. It has a steam-cylinder 3 inches in diameter, and a stroke of piston of 5 inches, driving a screw 26 inches in diameter and of 3 feet pitch. The maximum power of the engine is four or five times the nominal power. The

boiler is of the type usually adopted in semi-portable engines, and has a heating surface of 75 square feet. The engine weighs about 150 lbs. per nominal horse-power, and the boilers about 300 lbs.

The table on page 672 gives dimensions of the regular sizes of launches and their machinery as furnished by the New York Safety Steam-Power Company, the builders of the engine represented in Fig. 1425. Within the last few years the building of steam-launches for pleasure purposes has become a specialty, and the object of constructors has been to produce engines and boilers that combine the elements of power and strength with a minimum of weight. Single engines are commonly employed, with their reciprocating parts so balanced that the engines can be run at a high rate of speed without jar or noise. Steel is frequently used in the construction of the boilers, for the purpose of reducing the weight; and a high pressure of steam being carried, and the steam being allowed to expand in the cylinder, the performance of the machinery can be made quite economical. This is often of importance, since the size of the coal-bunkers can thus be considerably reduced. Steam-launches intended for use in salt water are often fitted with a simple form of surface condenser, consisting of a piece of pipe passing around the keel, into one end of which the exhaust steam is discharged, the water of condensation being drawn out at the other end by an air-pump, and thus being saved to be used again as feed-water. Losses from leakage are supplied from a reservoir of fresh water, which does not require to be very large, since the continuous runs of steam-launches are generally of short duration.

1425.



The *Scientific American* of March 8, 1879, contains a description of what is said to be the smallest steam-launch ever built. The hull is modeled after the nautilus pattern of canoe, being intended to carry only one person. The length of the boat over all is 14 feet; width, 28 inches; draught, forward 6 inches, astern 8 inches. The weight of the hull is 90 lbs.; boiler, 80 lbs.; engine, 25 lbs.; shaft, propeller, pump, etc., 20 lbs.; total, 215 lbs. The speed of the boat is about $4\frac{1}{2}$ miles an hour in smooth water, with a steam-pressure of 50 lbs. per square inch, the fuel consumed per day not exceeding 40 lbs. The boat was designed and constructed by Mr. J. Davidson of New York.

*Table showing Dimensions, etc., of Iron Vessels built by the Harlan & Hollingsworth Company, at Wilmington, Del.*

| NAME OF VESSEL. | DIMENSIONS OF HULL. | | | | |
|---|---|---|---|---|---|
| | Registered Tonnage. | Length between Perpendiculars. | Beam Moulded. | Depth from Base Line to Gunwale. | Load Draught. |
| | | Ft. | Ft. in. | Ft. in. | Ft. |
| New York.. / Lone Star... / Algiers..... / Morgan City | 2,300 | 275 | 38 4 | 30 0 | 18 |
| Carolina.......... | 984.18 | 250 | 35 0 | 14 0 | 9 |
| Republic.......... | 1,285.03 | 270 | 37 0 | 12 6 | *7 |

| NAMES OF VESSELS. | DIMENSIONS OF ENGINES AND BOILERS. | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Type of Engine. | Number of Cylinders. | Diameter of H. P. Cylinders. | Diameter of L. P. Cylinders. | Stroke of Piston. | Number of Boilers. | Type of Screw. | Diameter of Screw or Wheel. | Speed, Knots per Hour. | Revolutions per Minute. | Steam-Pressure, lbs. per sq. in. | Consumption of Coal in lbs. per Hour. |
| | | | In. | In. | Ft. | | | Ft. in. | | | | |
| New York.. / Lone Star... / Algiers..... / Morgan City | Vertical direct-acting, surface-condensing.... | 2 | 50 | 60 | 5 | 2 | 4-blade expanding. | 13 3 / pitch 2 0 | $11\frac{1}{2}$ | $62\frac{1}{2}$ | 60 | 2,240 |
| Carolina...... | Vertical beam.... | 1 | .. | 60 | 11 | 2 | Side wheels....... | 32 0 / face 8 9 | 20 | 23 | 45 | 3,360 |
| Republic..... | " " .... | 1 | .. | 66 | 12 | 2 | " " ....... | 33 6 / face 10 3 | 20 | 22 | 40 | 4,480 |

* With 2,500 passengers.

*Table showing Dimensions, etc., of Iron Vessels* built by John Roach & Son, at Chester, Pa., from* 1871 *to* 1879.

| NAME OF VESSEL. | Dimensions of Hull. Registered Tonnage. | Length between Perpendiculars. | Beam Moulded. | Depth from Base Line to Gunwale. | Load Draught. | Dimensions of Engines and Boilers. Type of Engine. | Number of Cylinders. | Diameter of H. P. Cylinders. | Diameter of L. P. Cylinders. | Stroke of Piston. | Number of Boilers. | Type of Screw. | Diameter of Screw or Wheel. | Speed, Knots per Hour. | Revolutions per Minute. | Steam-Pressure, in lbs. per sq. in. | Consumption of Coal, in lbs. per Hour. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Ft. in. | Ft. in. | Ft. in. | Ft. in. | | | In. | In. | Ft. in. | | | Ft. in. | | | | |
| S. S. San Antonio | 1,412.50 | 220 0 | 36 0 | 22 0 | 17 0 | Inverted condensing | 1 | .. | 48 | 4 0 | 2 | True | 13 0 | 11 | 55 | 35 | .... |
| Ferry-boat Garden City | 825.55 | 170 0 | 33 6 | 13 6 | 7 0 | Inclined side wheel | 1 | .. | 48 | 10 0 | 1 | Side wheel | 22 0 | 10 | 24 | 30 | .... |
| S. S. City of Chester | 1,106.21 | 197 0 | 33 6 | 17 4 | 11 6 | Compound | 2 | 24 | 44 | 3 9 | 2 | Hirsch | 10 0 | 11 | 68 | 80 | 950 |
| S. S. Colon | 2,685.75 | 282 0 | 40 0 | 30 6 | 19 0 | " | 2 | 50 | 86 | 3 6 | 4 | " | 16 3 | 12 | 50 | 60 | 2,450 |
| S. S. Colima | 2,905.64 | 294 6 | 40 0 | 30 6 | 19 6 | " | 2 | 51 | 88 | 3 6 | 4 | " | 16 3 | 12 | 50 | 60 | 2,561 |
| Ferry-boat Erie | 981 | 180 0 | 36 0 | 15 6 | 6 6 | Beam | 1 | .. | 46 | 11 0 | 1 | Side wheel | 22 0 | 10 | 22 | 30 | .... |
| S. S. City of Peking | 5,079.25 | 396 6 | 47 4 | 37 2 | 24 0 | Two compound | 4 | 57 | 88 | 4 6 | 10 | Hirsch | 20 3 | 14½ | 50 | 60 | 5,700 |
| " " Tokio | " | " | " | " | " | " " | " | " | " | " | " | " | " | " | " | " | " |
| " " Waco | 1,486.21 | 230 0 | 36 0 | 21 6 | 17 0 | Compound | 2 | 30 | 56 | 4 6 | 4 | True screw | 13 0 | 11 | 60 | 80 | 1,615 |
| S. Collier Perkiomen | 1,035.35 | 213 6 | 37 0 | 18 3 | 12 0 | " | 2 | 27 | 45 | 3 0 | 2 | " " | 11 0 | 10 | 62 | 50 | .... |
| " " Berks | 553.09 | 190 0 | 28 6 | 15 0 | 11 0 | " | 2 | 20½ | 34 | 2 6 | 1 | " " | 9 0 | 10 | 68 | 50 | .... |
| S. S. State of Texas | 1,548.66 | 234 0 | 36 0 | 21 6 | 17 0 | " | 2 | 30 | 56 | 4 6 | 4 | Hirsch | 13 0 | 12 | 60 | 80 | 1,615 |
| " City of Panama | 1,490.24 | 242 0 | 36 0 | 22 3 | 17 0 | " | 2 | 30 | 56 | 4 6 | 4 | " | 13 0 | 12 | 60 | 80 | 1,722 |
| " " Guatemala | 1,487.30 | 242 0 | 36 0 | 22 3 | 17 0 | " | 2 | 30 | 56 | 4 6 | 4 | " | 13 0 | 12 | 60 | 80 | 1,724 |
| " Geo. W. Elder | 1,561.82 | 242 0 | 38 0 | 22 11 | 17 0 | " | 2 | 30 | 56 | 4 6 | 4 | " | 13 0 | 13 | 65 | 80 | 1,726 |
| Tug Geo. E. Weed | 30.49 | 73 0 | 16 8 | 8 0 | 7 0 | Inverted H. P. | 1 | .. | 16 | 18 0 | 1 | True | 6 6 | 8 | 75 | 60 | .... |
| U. S. sloop Alert | 541 | 175 0 | 32 0 | 16 3 | 13 0 | Compound | 2 | 28¼ | 42½ | 3 6 | 5 | " | 12 0 | 12 | 72 | 80 | 1,726 |
| " " Huron | " | " | " | " | " | " | " | " | " | " | " | " | " | " | " | " | " |
| S. S. City of San Francisco | 3,009.25 | 331 1½ | 40 0 | 30 5 | 22 6 | " | 2 | 51 | 88 | 5 0 | 6 | Hirsch | 20 0 | 13 | 50 | 80 | 4,107 |
| " " New York | 3,019.56 | " | " | " | " | " | " | " | " | " | " | " | " | " | " | " | " |
| " " Sydney | 3,016.46 | " | " | " | " | " | " | " | " | " | " | " | " | " | " | " | " |
| U. S. monitor Miantonomoh | 2,025.75 | 250 0 | 55 0 | 16 6 | 14 0 | Two compound | 4 | 31 | 54 | 3 6 | 6 | " | 12 0 | .. | .. | 80 | .... |
| Spanish gun-boat Graciosa† | 72 | 91 0 | 15 0 | 5 8 | 3 0 | Inverted condensing | 4 | 8 | .. | 9 | 1 | " | 4 0 | 11 | 120 | 60 | .... |
| U. S. monitor Puritan† | 2,898 | 280 0 | 60 0 | 20 0 | 18 0 | Two compound | 4 | 51 | 88 | 3 6 | 10 | " | 15 0 | .. | .. | 80 | .... |
| Str. Newberne | 412.27 | 150 0 | 24 0 | 9 7 | 8 6 | Inverted condensing | 1 | 24 | .. | 3 0 | 1 | True | 8 0 | 11 | 75 | 60 | .... |
| S. S. Rio Grande | 2,566.48 | 290 0 | 39 0 | 22 10 | 13 6 | Compound | 2 | 34 | 60 | 4 6 | 4 | Hirsch | 14 0 | 12 | 63 | 80 | 2,315 |
| " Niagara | 2,265.28 | 272 0 | 38 1 | 24 10 | 17 0 | " | 2 | 34 | 60 | 4 6 | 4 | " | 14 3 | 13 | 63 | 80 | 2,315 |
| " Saratoga‡ | 2,285.65 | " | " | " | " | " | " | " | " | " | " | " | " | " | " | " | " |
| " City of Macon | 2,092.80 | 254 2 | 38 6 | 25 11 | 16 0 | " | 2 | 38 | 68 | 4 6 | 4 | " | 15 0 | 13 | 64 | 80 | 2,455 |
| " Western Texas | 1,121.12 | 226 5 | 34 0 | 17 5 | 10 0 | " | 2 | 24 | 44 | 3 9 | 2 | " | 11 6 | 11 | 66 | 80 | 922 |
| Panama Tug† | 105.30 | 91 0 | 18 0 | 6 10 | 5 0 | Inverted condensing | 2 | 20 | .. | 2 0 | 1 | Expanding | 6 9 | 10 | 100 | 60 | .... |
| S. S. City of Washington | 2,618.21 | 300 0 | 38 0 | 29 3 | 21 0 | Compound | 2 | 40 | 74 | 6 0 | 2 | " | 16 0 | 14½ | 60 | 70 | 3,950 |
| " " Savannah | 2,029.40 | 254 2 | 38 6 | 25 11 | 16 0 | " | 2 | 38 | 68 | 4 6 | 4 | Hirsch | 15 0 | 13 | 64 | 80 | 2,455 |
| " Oregon | 2,335.38 | 280 0 | 38 2 | 24 4 | 18 0 | " | 2 | 34 | 60 | 4 6 | 4 | " | 15 0 | 13 | 62 | 80 | 2,425 |
| " City of Rio de Janeiro | 3,548.30 | 345 10 | 38 6 | 30 4 | 23 0 | " | 2 | 42½ | 74 | 5 0 | 6 | " | 16 4 | 13 | 62 | 80 | 3,860 |
| " " Para | 3,532.25 | 345 10 | 38 6 | 30 4 | 23 0 | " | 2 | 42½ | 74 | 5 0 | 6 | " | 16 4 | 13 | 62 | 80 | 3,860 |
| " Saratoga (No. 2) | 2,426.13 | 299 10 | 38 0 | 23 6 | 19 0 | " | 2 | 40 | 74 | 4 6 | 4 | " | 15 6 | 14½ | 64 | 80 | 3,420 |
| " City of Columbus | 1,992.37 | 254 2 | 38 6 | 25 11 | 16 0 | " | 2 | 38 | 68 | 4 6 | 4 | " | 15 0 | 13 | 64 | 80 | 2,455 |
| " Gate City | 1,997.11 | 254 2 | 38 6 | 25 11 | 16 0 | " | 2 | 38 | 68 | 4 6 | 4 | " | 15 0 | 13 | 64 | 80 | 2,455 |
| " Guan Mir | 422.57 | 151 7 | 28 1½ | 13 1⅝ | 10 0 | Inverted condensing | 1 | 28 | .. | 3 0 | 1 | Expanding | 9 9 | 10 | 75 | 60 | 780 |

* Except the tugboat George E. Weed, which is of wood. † Twin-screw vessels. ‡ Sold to the Russian government, and converted into the corvette Africa.

*Table showing Dimensions, Performances, etc., of Steamers of Atlantic Lines.*

| NAME OF VESSEL. | Tonnage. | When built. | Material. | Length between Perpendiculars. | Mean Draught. | Beam, Extreme. | Depth. | Type of Engine. | Number of Steam Cylinders. | Diameter of Steam Cylinders. | Stroke. | Number of Boilers. | Type of Screw. | Diameter of Screw. | Pitch of Screw. | Maximum Speed. | Number of Revolutions of Screw corresponding. | Steam-Pressure corresponding. | Coal consumed in Pounds per Hour corresponding. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *White Star Line.* | | | | Ft. in. | Ft. in. | Ft. in. | Ft. in. | | | Inches. | In. | | | Feet. | Feet. | Knots. | | | |
| Britannic | 5,034 | 1874 | Iron. | 455 0 | 25 0 | 45 2 | 26 2 / 33 7 | Compound. | 4 | 48–83 | 60 | 8 | 4-bladed. | .... | .... | ... | .... | .... | ...... |
| Celtic | 3,867 | 1872 | " | 437 0 | 24 0 | 40 9 | 23 4 / 31 0 | " | 4 | 41–78 | 60 | 12 | " | 22* | 31* | 15* | 55* | 65* | ...... |
| Germanic | 5,008 | 1874 | " | 455 0 | 25 0 | 45 2 | 26 2 / 33 7 | " | 4 | 48–83 | 60 | 8 | " | .... | .... | .... | .... | .... | ...... |
| Baltic | 3,707 | 1871 | " | 420 0 | 24 0 | 40 9 | 23 4 / 31 0 | " | 4 | 41–78 | 60 | 12 | " | .... | .... | .... | .... | .... | ...... |
| Adriatic | 3,888 | 1871 | " | 437 0 | 24 0 | 40 9 | 23 4 / 31 0 | " | 4 | 41–78 | 60 | 12 | " | .... | .... | .... | .... | .... | ..... |
| Republic | 3,707 | 1871 | " | 420 0 | 24 0 | 40 9 | 23 4 / 31 0 | " | 4 | 41–78 | 60 | 12 | " | .... | .... | .... | .... | .... | ...... |
| *Inman Line.* | | | | | | | | | | | | | | | | | | | Per h. p. |
| City of Berlin | 5,491 | 1875 | Iron. | 489 0 | .... | 45 0 | 35 0 | Compound. | 2 | 72–120 | 66 | 18 | 4-bladed. | Various. | | 16 | 55 | 75 | 2.2 |
| " Chester | 4,566 | 1873 | " | 444 0 | .... | 44 0 | 34 0 | " | 2 | 72–120 | 66 | 14 | " | .... | | 15 | 55 | 65 | 2.5 |
| " Richmond | 4,607 | 1873 | " | 441 0 | .... | 43 6 | 34 6 | " | 2 | 76–120 | 60 | 10 | " | .... | | 15.5 | 55 | 60 | 2 |
| " Montreal | 4,490 | 1871 | " | 419 0 | .... | 44 0 | 34 6 | " | 2 | 77–112 | 54 | 8 | " | .... | | 13 | 54 | 50 | 3.4 |
| " Brussels | 3,775 | 1869 | " | 390 0 | .... | 40 6 | 34 6 | " | 4 | 35– 75 | 60 | 4 | " | .... | | 14.5 | 54 | 90 | 2.3 |
| " New York | 3,500 | 1865 | " | 375 0 | .... | 39 6 | 33 0 | " | 4 | 40– 71 | 60 | 4 | " | .... | | 13.5 | 54 | 75 | 2.2 |
| " Paris | 3,000 | 1866 | " | 398 0 | .... | 40 6 | 26 0 | Hor. trunk. | 2 | 89– 82 | 42 | 6 | " | .... | | 14 | 55 | 30 | 8.4 |
| " Limerick | 2,700 | 1855 | " | 331 0 | .... | 30 6 | 30 6 | Compound. | 2 | 36– 72 | 42 | 3 | " | .... | | 11 | 60 | 60 | 3.2 |
| *Liverpool and G. W. SS. Line.* | | | | | | | | | | | | | | | | | | | Per hour. |
| Nevada | 3,350 | 1868 | Iron. | 345 6 | 24 4 | 43 4 | 20 1 / 27 8 | Inverted s. a. single | 2 | 63.5 | 48 | 2 | True screw. | 20 | 26 | 12.5 | 53 | 34 | 6,346.6 |
| Idaho | .... | 1869 | " | 345 3 | 24 4 | 43 4 | 20 1 / 27 5 | " | 2 | 63.5 | 48 | 2 | ........ | 20 | 26 | 12.5 | 51 | 34 | 6,346.6 |
| Wyoming | 3,716 | 1870 | " | 366 2 | 24 6 | 43 2 | 19 3 / 26 8 | Compound. | 2 | 60–120 | 42 | 2 | ........ | 19 | 27 | 14 | 55 | 74 | 6,346.6 |
| Wisconsin | 3,720 | 1870 | " | 366 0 | 24 6 | 43 2 | 19 3 / 26 6 | " | 2 | 60–120 | 42 | 2 | ........ | 19 | 26 | 14 | 58 | 74 | 6,346.6 |
| Montana | 4,320 | 1874 | " | 400 4 | 25 0 | 43 7 | 32 2 / 40 7 | " | 8 | (2) 60–108.5 | 42 | 6 | ........ | 21 | 28 | 15 | 58 | 80 | 9,333 |

* These figures give a fair average of general performance of the vessels named.

*Table showing Dimensions, Performances, etc., of Steamers of Atlantic Lines (continued).*

| NAME OF VESSEL. | Tonnage. | When built. | Material. | Length between Perpendiculars. | Mean Draught. | Beam, Extreme. | Depth. | Type of Engine. | Number of Steam Cylinders. | Diameter of Steam Cylinders. | Stroke. | Number of Boilers. | Type of Screw. | Diameter of Screw. | Pitch of Screw. | Maximum Speed. | Number of Revolutions of Screw corresponding. | Steam-Pressure corresponding. | Coal consumed in Pounds per Hour corresponding. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *Anchor Line.* | | | | Ft. in. | Ft. in. | Ft. in. | Ft. in. | | | Inches. | In. | | | Ft. in. | Ft. in. | Knots. | | | |
| Devonia | 4,270 | 1877 | Iron. | 400 3 | .... | 42 5 | 33 2 | Compound. | 2 | 59–107 | 48 | 6 | 4-bladed. | .... | .... | .... | .... | .... | ...... |
| Anchoria | 4,170 | 1875 | " | 408 0 | .... | 40 1 | 33 8 | " | 2 | 59–107 | 48 | 6 | " | .... | .... | .... | .... | .... | ...... |
| Bolivia | 4,051 | 1874 | " | 400 0 | .... | 40 0 | 33 0 | " | 2 | 59–107 | 48 | 6 | " | .... | .... | .... | .... | .... | ...... |
| Ethiopia | 4,005 | 1873 | " | 402 0 | .... | 40 2 | 33 0 | " | 2 | 59–107 | 48 | 6 | " | .... | .... | .... | .... | .... | ...... |
| Victoria | 3,243 | 1872 | " | 360 0 | .... | 40 1 | 31 9 | " | 2 | 57–107 | 48 | 6 | " | .... | .... | .... | .... | .... | ...... |
| California | 3,288 | 1872 | " | 361 1 | .... | 40 5 | 31 6 | " | 2 | 57–103 | 48 | 6 | " | .... | .... | .... | .... | .... | ...... |
| Alsatia | 2,791 | 1876 | " | 356 0 | .... | 36 2 | 29 4 | " | 2 | 87–118 | 48 | 6 | " | .... | .... | .... | .... | ... | ...... |
| Elysia | 2,734 | 1873 | " | 351 0 | ... | 35 1 | 29 7 | " | 2 | 46.5– 83 | 48 | 4 | " | .... | .... | .... | .... | .... | ...... |
| Utopia | 2,732 | 1874 | " | 350 2 | ... | 35 2 | 29 9 | " | 2 | 46.5– 83 | 48 | 4 | " | .... | .... | .... | .... | .... | ...... |
| Australia | 2,241 | 1870 | " | 324 6 | ... | 35 2 | 29 3 | " | 2 | 41– 73 | 42 | 4 | " | .... | .... | .... | .... | .... | ...... |
| Anglia | 2,148 | 1869 | " | 325 3 | .... | 35 0 | 28 7 | " | 2 | 41– 73 | 42 | 4 | " | .... | .... | .... | .... | .... | ...... |
| *North German Lloyds.* | | | | | | | | | | | | | | | | | | | |
| Neckar | 3,500 | 1873 | Iron. | 370 0 | 22 6 | 40 0 | .... | Compound. | 2 | 96–72 | 60 | 8 | 4-bladed. | 17 6 | 30 0 | 15 | 60 | 60 | 4,000 |
| Mosel | " | 1872 | " | 370 0 | 22 0 | 40 0 | .... | Single. | 2 | 90 | 60 | 10 | " | 17 6 | 30 0 | 14 | 52 | 26 | 6,000 |
| Oder | " | 1873 | " | 370 0 | 22 6 | 40 0 | .... | Compound. | 2 | 96–72 | 60 | 8 | " | 17 6 | 30 0 | 15 | 60 | 60 | 4,000 |
| Weser | " | 1867 | " | 360 0 | 22 6 | 38 0 | .... | Single. | 2 | 84 | 48 | 8 | " | 17 0 | 28 0 | 15 | 60 | 25 | 4,000 |
| *General Transatlantic Line (French).* | | | | | | | | | | | | | | | | | | | |
| Labrador, France, Amérique | 4,500 | 1865 to 1875 | Iron | 384 0 | 20 7 | 43 9 | 23 3 | Compound. | 4 | 74–40 | 49 | 6 | Griffith's. | 18 5 | 27 8 | 14 | 58 | 60 | 6,400 |
| *State Line.* | | | | | | | | | | | | | | | | | | | |
| Virginia, Nevada, Indiana, Pennsylvania, Georgia, Louisiana, Alabama | 2,550 | 1873 | Iron. | 330 0 | 22 0 | 36 0 | 28 0 | Compound. | 2 | 51–84 | 48 | 2 | 4-bladed, increasing pitch | 18 0 | 26 0 | 13 | 52 | 70 | 3,710 |

*Table showing Dimensions and Performances of several Paddle-wheel Steamers (Fall River Line).*

| NAME OF VESSEL. | Tonnage. | When Built. | Material. | Length between Perpendiculars. | Mean Draught. | Beam, extreme. | Depth. | Type of Engine. | Number of Steam Cylinders. |
|---|---|---|---|---|---|---|---|---|---|
| | | | | Feet. | Ft. in. | Feet. | Feet. | | |
| Providence | 3,000 | 1867 | Wood. | 362 | 9 6 | 48 | 16 | Beam, condensing. | 1 |
| Bristol | 3,000 | 1867 | Wood. | 362 | 6 0 | 48 | 16 | " | 1 |
| Old Colony | 1,957 | 1865 | Wood. | 310 | 10 0 | 42 | 14 | " | 1 |
| Newport | 2,200 | 1865 | Wood. | 332 | 11 6 | 43 | 14 | " | 1 |

| NAME OF VESSEL. | Diameter of Steam Cylinders. | Stroke. | No. of Boilers. | Diameter of Paddle Wheels. | No. of Buckets. | Area of Bucket. | Maximum Speed. | No. of Revolutions of Wheel corresponding. | Steam-Pressure corresponding. | Coal Consumed in Tons per hour corresponding. |
|---|---|---|---|---|---|---|---|---|---|---|
| | Inches. | Feet. | | Ft. in. | | Feet. | Per hour. | | Pounds. | |
| Providence | 110 | 12 | 3 | 39 4 | 48 | 30 | 17 knots | 1,050 | 22 | 3½ |
| Bristol | 110 | 12 | 3 | 39 4 | 48 | 30 | 17 knots | 1,050 | 22 | 3½ |
| Old Colony | 81 | 12 | 2 | 36 0 | 60 | 26 | 16 knots | 990 | 27 | 2¼ |
| Newport | 85 | 12 | 4 | 36 0 | 60 | 26 | 16 knots | 990 | 27 | 2⅛ |

*Table showing Comparative Dimensions, etc., of several Famous Atlantic Steamers.**

| NAME OF SHIP. | Owners. | Where Built. | Year. | DIMENSIONS. Length. | Breadth. | Depth. | Tonnage. | Nominal Horse-power. | How Propelled. |
|---|---|---|---|---|---|---|---|---|---|
| | | | | Ft. in. | Ft. in. | Ft. in. | | | |
| Britannia | Cunard Line | Greenock | 1840 | 230 0 | 34 5 | 22 5 | 1,150 | 440 | Paddles. |
| Great Britain | Great Western Line | Bristol | 1843 | 274 2 | 48 2 | 31 5 | 3,270 | 500 | Screw. |
| Asia | Cunard Line | Greenock | 1850 | 268 0 | 45 0 | 24 1 | 2,227 | 750 | Paddles. |
| Arctic | Collins " | New York | 1850 | 290 0 | 45 0 | 31 5 | 2,860 | 1,000 | " |
| Persia | Cunard " | Glasgow | 1855 | 360 0 | 45 0 | 32 0 | 3,300 | 900 | " |
| Great Eastern | Great Eastern S. S. Co. | Millwall | 1858 | 679 6 | 82 8 | 48 2 | 18,915 | { 1,000<br>{ 1,600 | "<br>Screw. |
| Scotia | Cunard Line | Glasgow | 1862 | 379 0 | 47 8 | 30 5 | 3,871 | 1,000 | Paddles. |
| Oceanic | White Star Line | Belfast | 1871 | 420 0 | 40 9 | 31 0 | 3,707 | 600 | Screw. |

*Comparative Table showing Rapid Passages made by Atlantic Steamers from 1840 to 1877.*

HOMEWARD.

| YEAR. | Month. | Name of Steamer. | Owners. | From | To | Distance Run in Knots. | Time Occupied. D. H. M. |
|---|---|---|---|---|---|---|---|
| 1840 | July | Britannia | Cunard Line | Halifax | Liverpool | 2,573 | 10 0 0 |
| 1841 | July | Acadia | " " | " | " | 2,534 | 9 21 0 |
| 1846 | May | Great Britain | Great Western Line | New York | " | 3,209 | 10 23 0 |
| 1852 | February | Atlantic | Collins Line | " | Queenstown | 2,712 | 9 17 15 |
| 1856 | | Persia | Cunard " | " | " | 2,732 | 9 1 45 |
| 1858 | | Pacific | Collins " | St. Johns | Galway | 1,720 | 6 1 0 |
| 1863 | December | Scotia | Cunard " | New York | Queenstown | 2,731 | 8 3 0 |
| 1869 | December | City of Brussels | Inman " | " | " | 2,687 | 7 22 3 |
| 1872 | October | Polynesian | Allan " | Quebec | Moville | 2,379 | 7 18 55 |
| 1873 | January | Baltic | White Star Line | New York | Queenstown | 2,843 | 7 20 9 |
| 1875 | October | City of Berlin | Inman Line | " | " | 2,820 | 7 15 28 |
| 1876 | February | Germanic | White Star Line | " | " | 2,894 | 7 15 17 |
| 1876 | December | Britannic | " " | " | " | 2,882 | 7 12 41 |

OUTWARD.

| YEAR. | Month. | Name of Steamer. | Owners. | From | To | Distance Run in Knots. | Time Occupied. D. H. M. |
|---|---|---|---|---|---|---|---|
| 1840 | July | Britannia | Cunard Line | Liverpool | Boston | 2,755 | 14 8 0 |
| 1840 | August | Acadia | " " | " | Halifax | 2,487 | 11 4 0 |
| 1845 | July | Great Britain | Great Western Line | Bristol | New York | 2,988 | 13 21 0 |
| 1846 | | Europa | Cunard Line | Liverpool | " | 3,017 | 11 3 0 |
| 1853 | | Baltic | Collins " | Queenstown | " | 2,721 | 9 16 33 |
| 1864 | | Scotia | Cunard " | " | " | 2,783 | 8 15 45 |
| 1866 | July | Scotia | " " | " | " | 2,851 | 8 4 34 |
| 1867 | November | City of Paris | Inman " | " | " | 2,700 | 8 4 1 |
| 1869 | August | City of Paris | " " | " | Halifax | 2,258 | 6 19 5 |
| 1872 | May | Adriatic | White Star Line | " | New York | 2,778 | 7 23 17 |
| 1875 | September | City of Berlin | Inman Line | " | " | 2,829 | 7 18 2 |
| 1876 | June | Britannic | White Star Line | " | " | 2,854 | 7 16 36 |
| 1876 | November | Britannic | " " | " | " | 2,795 | 7 13 11 |
| 1877 | April | Germanic | " " | " | " | 2,830 | 7 11 37 |
| 1877 | August | Britannic | " " | " | " | 2,802 | 7 10 53 |

* This table and those following are from a valuable paper on "Transatlantic Lines and Steamships," by Arthur T. Maginnis, read before the Liverpool Engineering Society, January 30, 1878, to which the reader is referred for further particulars.

*Table showing Average Passages of Steamships of Atlantic Lines from* 1850 *to* 1877.

OUTWARD.

| YEAR. | Cunard Line. | | | Collins Line. | | | Inman Line. | | | Guion Line. | | | National Line. | | | White Star Line. | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | D. | H. | M. | D. | H. | M. | D. | H. | M. | D. | H. | M. | D. | H. | M. | D. | H. | M. |
| 1850 | 13 | 0 | 0 | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. |
| 1852 | 12 | 19 | 26 | 11 | 10 | 26 | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. |
| 1855 | 12 | 12 | 0 | 11 | 22 | 40 | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. |
| 1866 | 10 | 11 | 34 | .. | .. | .. | 11 | 15 | 18 | .. | .. | .. | 10 | 11 | 40 | .. | .. | .. |
| 1873 | 10 | 16 | 40 | .. | .. | .. | 10 | 22 | 4 | 12 | 6 | 38 | 11 | 21 | 36 | 9 | 19 | 48 |
| 1875 | 10 | 17 | 24 | .. | .. | .. | 10 | 20 | 45 | 11 | 8 | 47 | 12 | 1 | 19 | 9 | 16 | 33 |
| 1876 | 10 | 13 | 32 | .. | .. | .. | 10 | 1 | 44 | 10 | 23 | 45 | 11 | 16 | 45 | 8 | 21 | 14 |
| *1877 | 10 | 0 | 58 | .. | .. | .. | 8 | 21 | 17 | 9 | 16 | 30 | 10 | 23 | 12 | 8 | 13 | 39 |
| HOMEWARD. | | | | | | | | | | | | | | | | | | |
| 1850 | 12 | 16 | 0 | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. |
| 1855 | 11 | 12 | 0 | 10 | 20 | 0 | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. |
| 1866 | 9 | 4 | 39 | .. | .. | .. | 10 | 11 | 40 | .. | .. | .. | .. | .. | .. | .. | .. | .. |
| 1873 | 9 | 7 | 59 | .. | .. | .. | 10 | 0 | 2 | 10 | 20 | 18 | 10 | 14 | 16 | 8 | 22 | 39 |
| 1876 | 9 | 4 | 48 | .. | .. | .. | 8 | 17 | 52 | 9 | 20 | 4 | 10 | 7 | 35 | 8 | 12 | 13 |
| *1877 | 9 | 7 | 7 | .. | .. | .. | 8 | 20 | 36 | 9 | 13 | 51 | 10 | 5 | 31 | 8 | 10 | 30 |

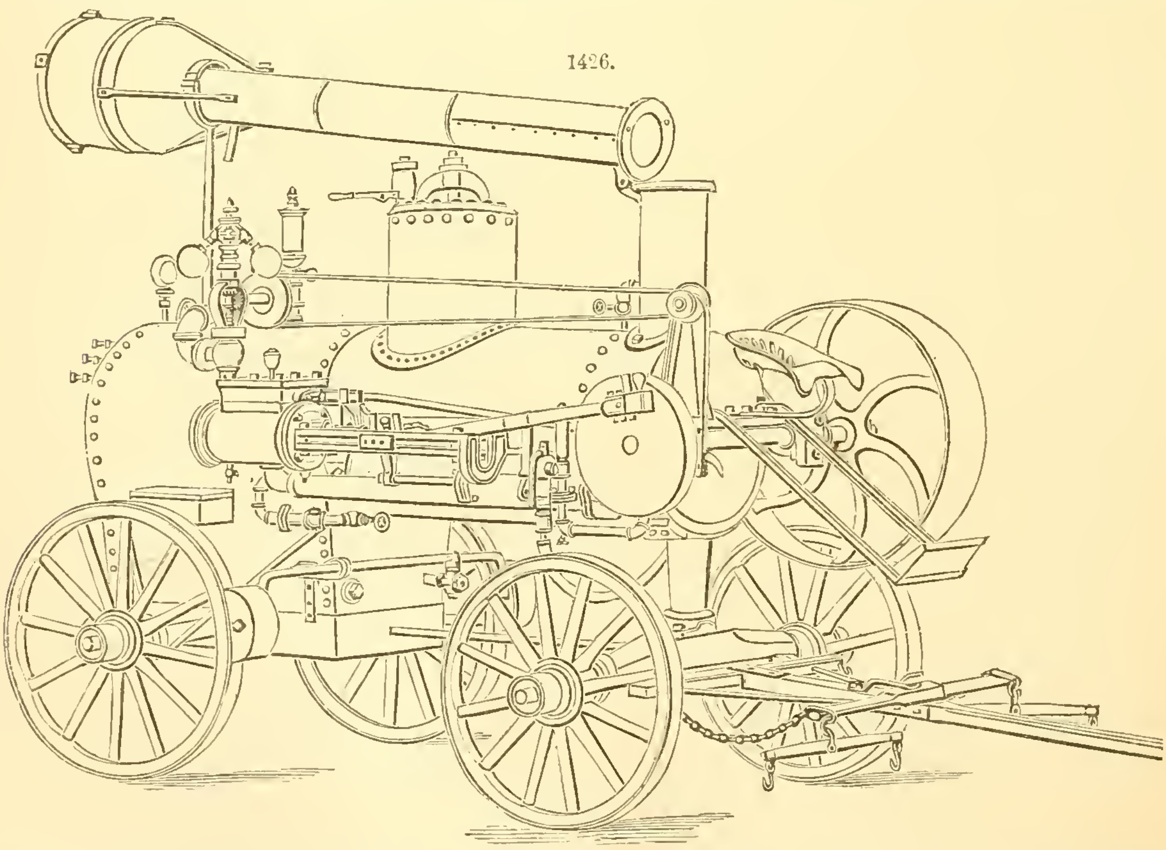
*Table showing Dimensions of Steam-Yachts and Machinery.*

| HULL. | | | Tonnage, Carpenter's Measurement. | ENGINE. | | | | PROPELLER. | | BOILER. | | | WEIGHT. | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | CYLINDER. | | SHAFT. | | | | | | | | |
| Length over all. | Beam. | Draught. | | Diameter. | Stroke. | Diameter. | Length. | Diameter. | Pitch. | Diameter of Shell. | Height of Shell. | Heating Surface. | Engine Wheel and Shaft. | All Machinery. |
| Ft. | Ft. in. | Ft. in. | | In. | In. | In. | In. | In. | Ft. | In. | In. | Sq. Ft. | Lbs. | Lbs. |
| 25 | 5 8 | 2 3 | 4 | 3 | 5 | $1\frac{3}{8}$ | 12 | 26 | 3 | 28 | 45 | 75 | 350 | 1,500 |
| 28 | 5 10 | 2 4 | 5 | $3\frac{1}{2}$ | 5 | $1\frac{1}{2}$ | 13 | 28 | 3 | 30 | 46 | 90 | 375 | 1,700 |
| 32 | 6 4 | 2 6 | 6 | 4 | 6 | $1\frac{5}{8}$ | 15 | 30 | $3\frac{1}{2}$ | 33 | 48 | 115 | 500 | 2,000 |
| 38 | 7 6 | 3 2 | 10 | $5\frac{1}{2}$ | 7 | 2 | 16 | 36 | 4 | 36 | 56 | 170 | 750 | 3,000 |
| 50 | 9 0 | 3 6 | 16 | 7 | 9 | $2\frac{1}{8}$ | 18 | 42 | 5 | 46 | 76 | 246 | 1.200 | 4.800 |
| 60 | 10 0 | 4 2 | 26.5 | 9 | 12 | 3 | 25 | 48 | 5 | 50 | 82 | 332 | 2,700 | 7.500 |
| 68 | 11 0 | 4 8 | 37.5 | 10 | 12 | $3\frac{1}{4}$ | 30 | 54 | 6 | 54 | 86 | 402 | 3,200 | 8,500 |
| 75 | 12 0 | 4 10 | 43 | 12 | 12 | $3\frac{1}{2}$ | 35 | 56 | 7 | 60 | 90 | 504 | 4,000 | 10,000 |

For works for reference, see ENGINES, HEAT. R. H. B.

ENGINES, STEAM, PORTABLE AND SEMI-PORTABLE. Portable engines, properly speaking, are engines and boilers mounted on wheels, which can be drawn or propelled from place to place,

1426.



and need no special preparation beyond blocking the wheels when it is desired to run them. Such engines are commonly employed on farms, where it is often convenient to do the work of threshing,

* First nine months.

etc., in the fields. Engines either attached directly to the boilers or placed on the same casting, so that no special foundation is required, form the semi-portable class. Horizontal fire-tube boilers are generally used for portable engines, and vertical fire-tube boilers for the semi-portable.

PORTABLE ENGINES.—The immense demand for engines of moderate power, easily managed, and ready for work when delivered, has been thoroughly appreciated by the engine manufacturers of this country; so that, in selecting examples, the object is rather to convey an idea of modern practice in this branch of engineering than to exhibit all varieties.

1427.

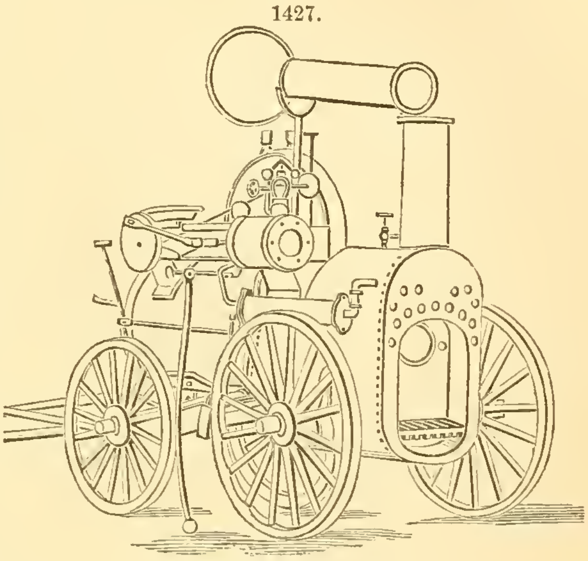


Fig. 1426, *the Lane & Bodley portable engine*, is fairly representative of one great division, viz., portable engines with locomotive boilers, plain slide-valves, and fixed cut-offs, the speed being regulated by the action of the governor upon the throttle-valve.

In *Whitman & Burrell's portable engine*, Fig. 1427, it will be seen that a return tubular boiler is used. The cut-off of this engine can also be readily changed when desired.

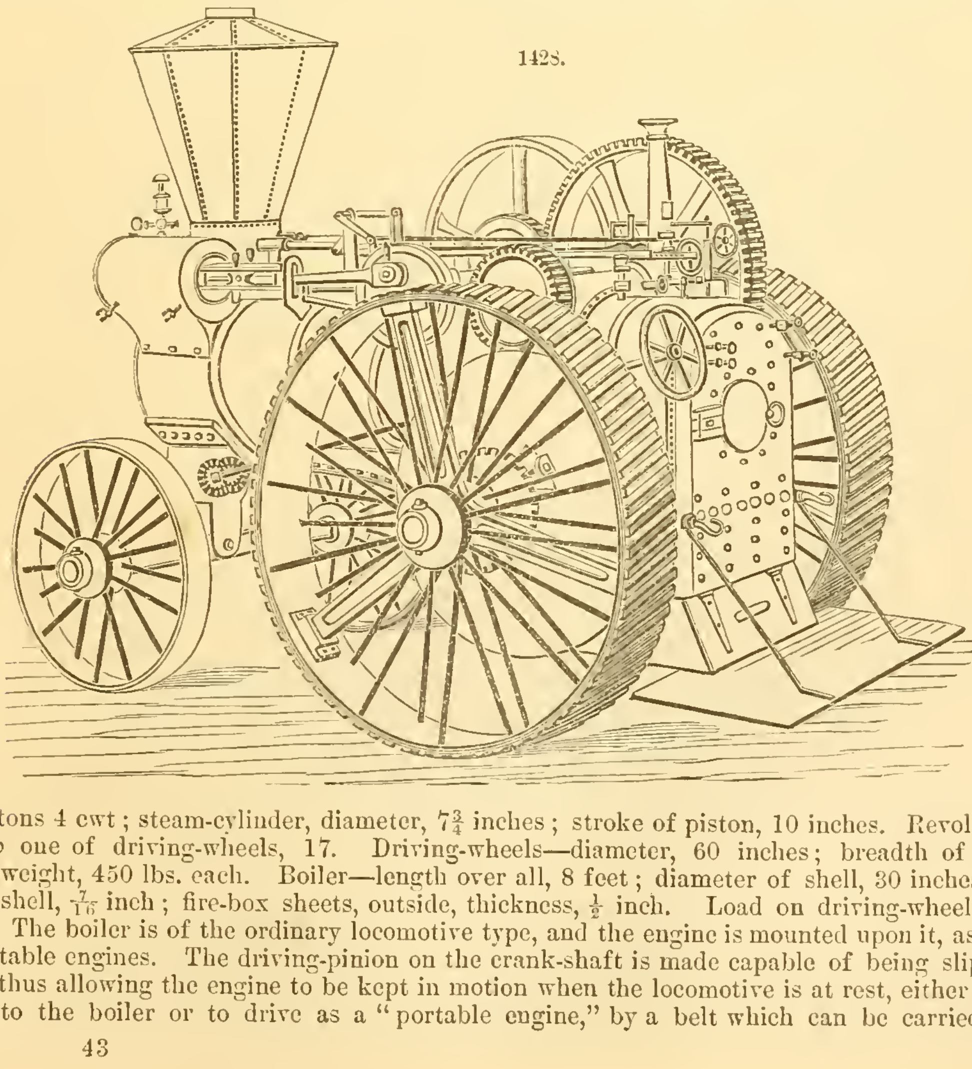
Portable engines designed with a special view to economy and lightness have cut-offs that are adjusted by the action of the governor, and are designed to be run at a high speed. The cylinders are usually jacketed also with live steam.

Remarks have frequently been made upon the absurdity of using animal power to draw a portable engine from place to place, since it is powerful enough not only to propel itself, but also to haul a threshing machine or the like in addition. Several self-propelling portables have been put into operation, and have worked very satisfactorily; and while this is rather the exception in present practice, many manufacturers are ready to build such engines when called for.

Fig. 1428 shows *the Mills self-propelling engine*, with locomotive boiler, jacketed cylinder, balanced valve, automatic cut-off, and reversing gear.

Fig. 1429 represents an improved form of traction engine or road locomotive built by Messrs. Aveling & Porter of England. The following are the principal dimensions: Weight of engine, com-

1428.



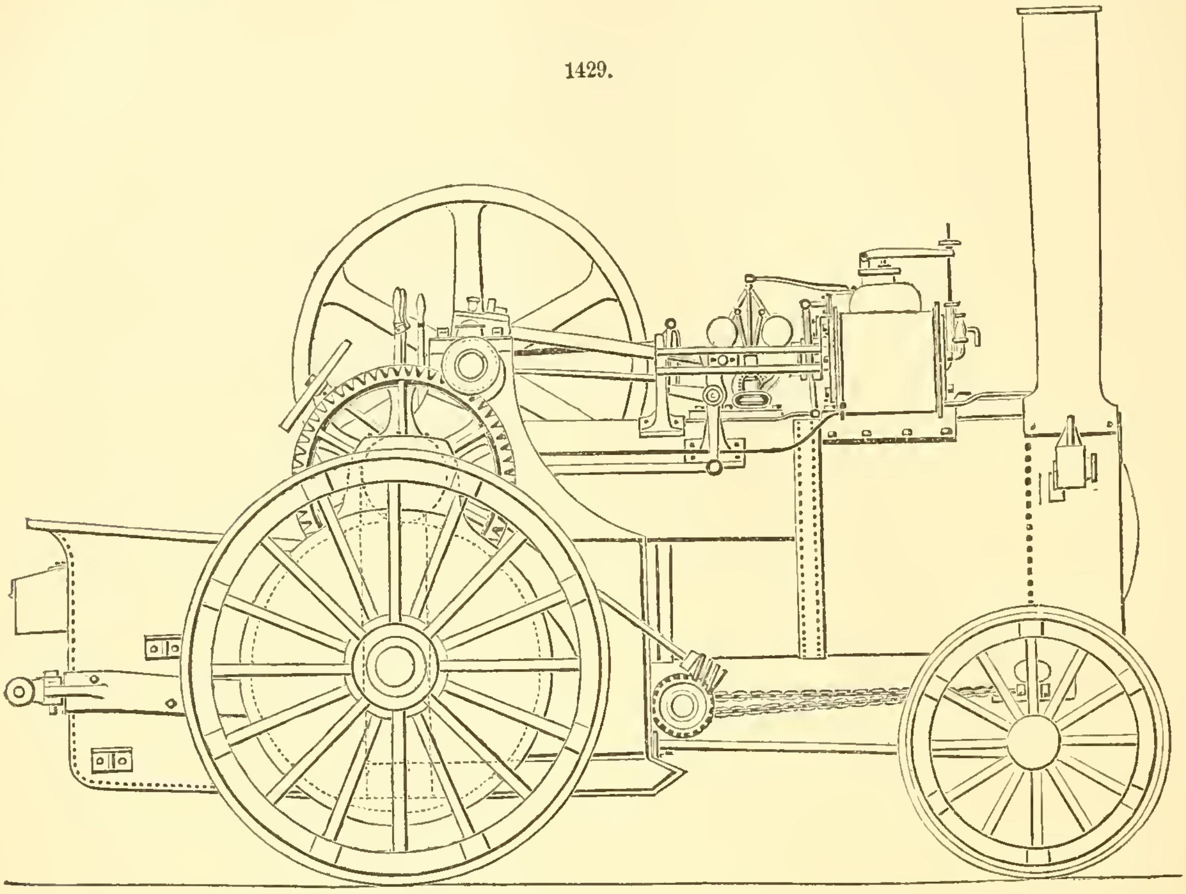
plete, 5 tons 4 cwt; steam-cylinder, diameter, $7\frac{3}{4}$ inches; stroke of piston, 10 inches. Revolutions of crank to one of driving-wheels, 17. Driving-wheels—diameter, 60 inches; breadth of tire, 10 inches; weight, 450 lbs. each. Boiler—length over all, 8 feet; diameter of shell, 30 inches; thickness of shell, $\frac{7}{16}$ inch; fire-box sheets, outside, thickness, $\frac{1}{2}$ inch. Load on driving-wheels, 4 tons 10 cwt. The boiler is of the ordinary locomotive type, and the engine is mounted upon it, as is usual with portable engines. The driving-pinion on the crank-shaft is made capable of being slipped out of gear, thus allowing the engine to be kept in motion when the locomotive is at rest, either to pump water into the boiler or to drive as a "portable engine," by a belt which can be carried on the

43

pulley, $4\frac{1}{2}$ feet in diameter and 5 inches face, which is fitted to act as a fly-wheel. When used as a portable engine, regulation is effected by means of a fly-ball governor conveniently attached.

The principal feature of this engine is the connection between the gearing and the driving-wheels,

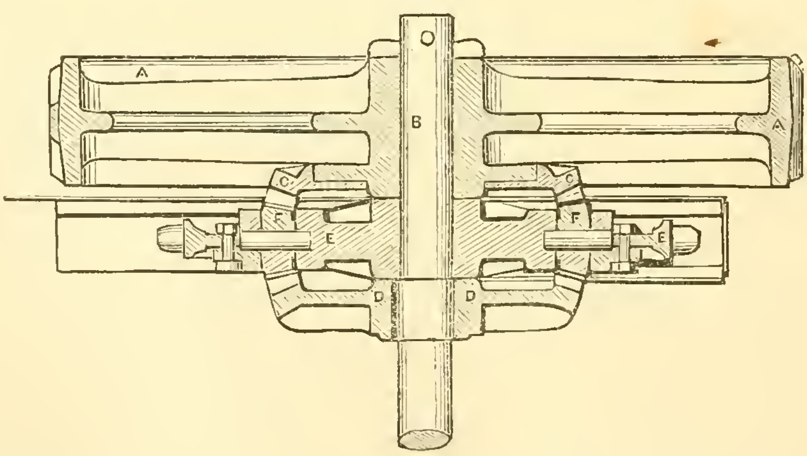
1429.



which is effected by the differential gear shown in Fig. 1430. One wheel, *A*, turns freely on the driving-axle at *B*, while the other driving-wheel is keyed fast. The latter is not shown in the cut. A bevel-gear, *C*, is bolted on the hub of the wheel *A*, and a similar gear, *D*, is keyed to the driving-axle. Between these revolves a spur-gear, *E*, which is driven by the engine, and which carries two small bevel-pinions, *F F*, the latter engaging both bevel-wheels, *C* and *D*, their axles being in the plane of revolution of the large gear *E*. An examination of the combination will show that, resistances being equal on both wheels, if the spur-gear *E* be turned, it will carry with it both driving-wheels at the same time with equal angular velocities, the effort exerted by the engine being equal at both wheels at all times. If the engine be turning a corner, however, the greater resistance on the inside wheel retards that, while the outer wheel necessarily moves more rapidly over its longer path, and, while the engine still exerts the same force on both wheels, the work done is distributed unequally between them through the then revolving bevel-pinions, without loss and without either wheel being necessarily slipped or disengaged.

The following summary of results is taken from a report of tests of this engine, conducted by Prof. R. H. Thurston, at South Orange, N. J., in 1872 (see *Journal of the Franklin Institute*): "A

1430.

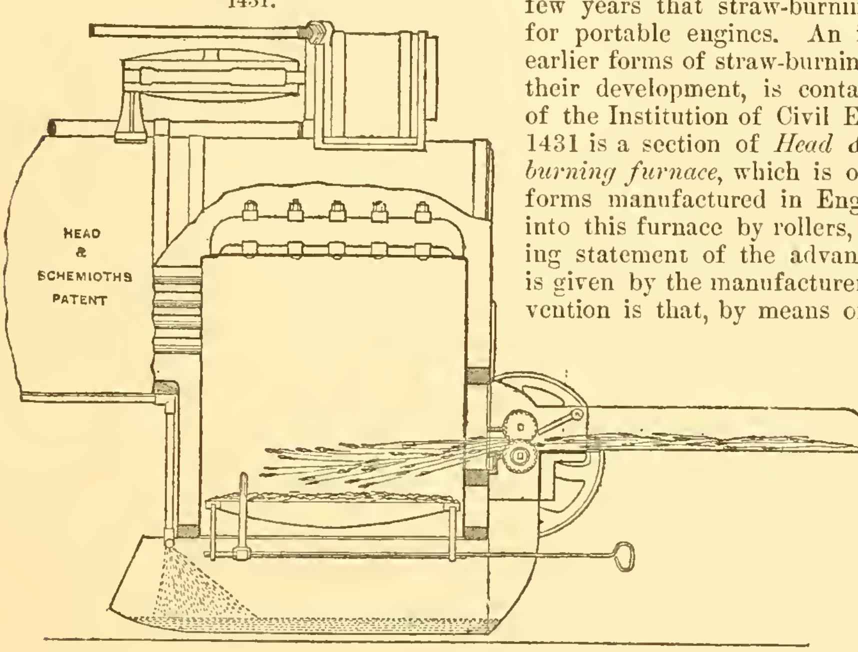



traction engine may be so constructed as to be easily and rapidly manœuvred on the common road; and an engine weighing over 5 tons may be turned continuously without difficulty on a circle of 18 feet radius, or even on a road but little wider than the length of the engine. A locomotive of 5 tons

4 cwt. has been constructed capable of drawing on a good road 23,000 lbs. up a grade of 533 feet to the mile at the rate of 4 miles per hour; and one might be constructed to draw more than 63,000 lbs. up a grade of 225 feet to the mile at the rate of 2 miles an hour. It was further shown that the coefficient of traction, with heavily-laden wagons on a good macadamized road, is not far from .04. The traction power of the engine was found equal to 20 horses. The weight, exclusive of that of the engine, that could be drawn on a level road, was 163,452 lbs.; and the amount of fuel required was estimated at 500 lbs. per day. The advantages claimed for the traction engine over horse-draught are: No necessity for a limitation of working hours; a difference in first cost in favor of steam; and in heavy work on a common road, the expense by steam is less than 25 per cent. of the average cost of horse power, a traction engine capable of doing the work of 25 horses being operated at as little expense as 6 or 8 horses. The cost of hauling heavy loads has been estimated at 7 cents per ton per mile." A detailed description of a traction engine especially suited for light agricultural work, and built by Messrs. Ransomes, Sims & Head, of Ipswich, England, will be found in *Engineering*, xxvi., 450.

The use of an engine on a farm for threshing purposes renders it desirable that the straw, which is ordinarily of little value, should be used as fuel if possible. This was formerly effected in furnaces under stationary boilers, and it is only within a few years that straw-burning boilers have been used for portable engines. An interesting account of the earlier forms of straw-burning furnaces and boilers, and their development, is contained in the "Proceedings of the Institution of Civil Engineers," vol. xlviii. Fig. 1431 is a section of *Head & Schemioth's patent straw-burning furnace*, which is one of the most successful forms manufactured in England. The straw is forced into this furnace by rollers, as shown; and the following statement of the advantages of this arrangement is given by the manufacturers: "The theory of the invention is that, by means of a continuous mechanical feed, the fuel can be forced into the furnace in a thin stream in the form of a fan, and the fresh fuel is practically held in suspension for a short time, allowing the separate stalks to become immersed in the flames, and the long pieces of straw, reeds, or brushwood to have the effect of stirring up the half-burnt material in the furnace, thus keeping the whole in motion, besides permitting a proper ingress of atmospheric air, which is necessary for the rapid combustion of vegetable matter." Mr. Head gives, from numerous experiments, the following relation between different kinds of fuel:

1431.




"1 lb. of good coal
2 lbs. of dry peat
2.25 to 2.3 lbs. of dry wood
2.75 to 3 lbs. of cotton stalks or brushwood
3.25 to 3.75 lbs. of wheaten or barley straw
} will evaporate 8 lbs. of water in an ordinary tubular boiler."

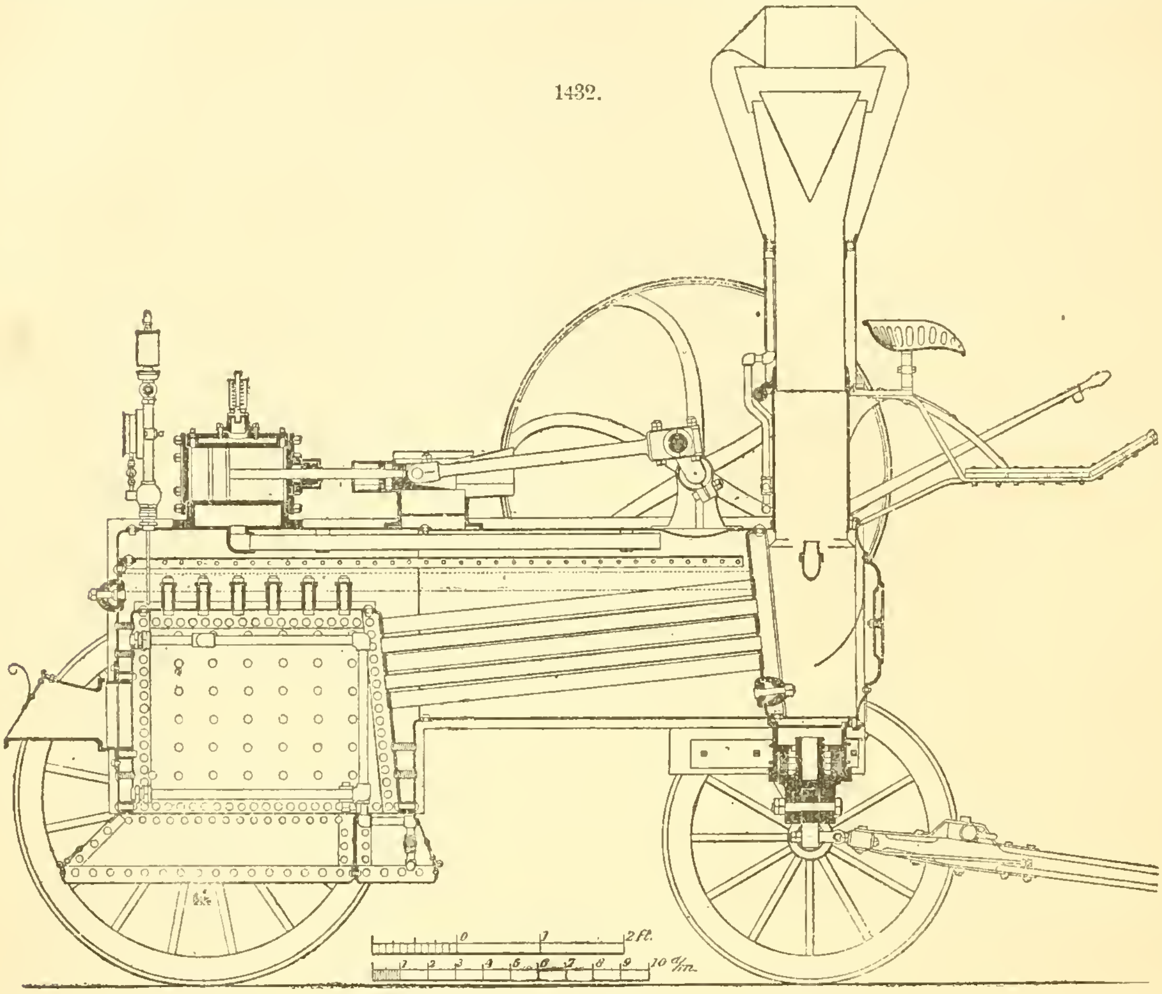
In Messrs. Clayton & Shuttleworth's straw-burning furnace the grate is placed in a supplementary fire-box, and the grate-bars are of such shape that they come close together at the front, forming a wide dead-plate, and only about one bar in three runs the whole length of the furnace. Experiments were made with a portable engine having this furnace by Prof. Radinger (see *Engineering* for Dec. 14, 1877), and it was found that the consumption of straw per net horse-power per hour was 12.4 lbs.

*The Hoadley portable engine*, Figs. 1432 to 1435, has been chosen as a good representative of advanced practice in the United States; and the straw-burning attachment, Figs. 1432 and 1434, is specially worthy of notice. A somewhat detailed description of the illustrations is appended. The boiler is strengthened by a horizontal diaphragm in the steam-space, which is also designed to prevent priming. There is also a dry pipe in the steam-space. A slight depression in the boiler between the shaft-bearings allows the engine to be lowered about 2 inches. The smoke-pipe is surrounded by a casing, which furnishes a cooler surface near the driver's back. A spark-arrester (see Fig. 1432) is fitted to the smoke-pipe. The central cone shown in the figure deflects the products of combustion, so that they are discharged with considerable force, in jets, between the cone and the enlarged end of the smoke-pipe. These jets strike the inclined surface under the conical cover, and are deflected outward and downward. Solid particles go downward to the casing, and on passing near the conical ring, which is open at both ends, are drawn up through the angular space between this ring and the smoke-pipe, to repeat the deflection until caught or worn to dust. The gaseous products of combustion escape in a continuous stream through the central outlet, which is 13 inches in diameter. There is a small steam-pipe opening into the casing, for blowing out the solid particles from time to time, after the sparks are extinguished.

The straw-burning apparatus, Figs. 1432 and 1434, consists of six independent series of pipes,

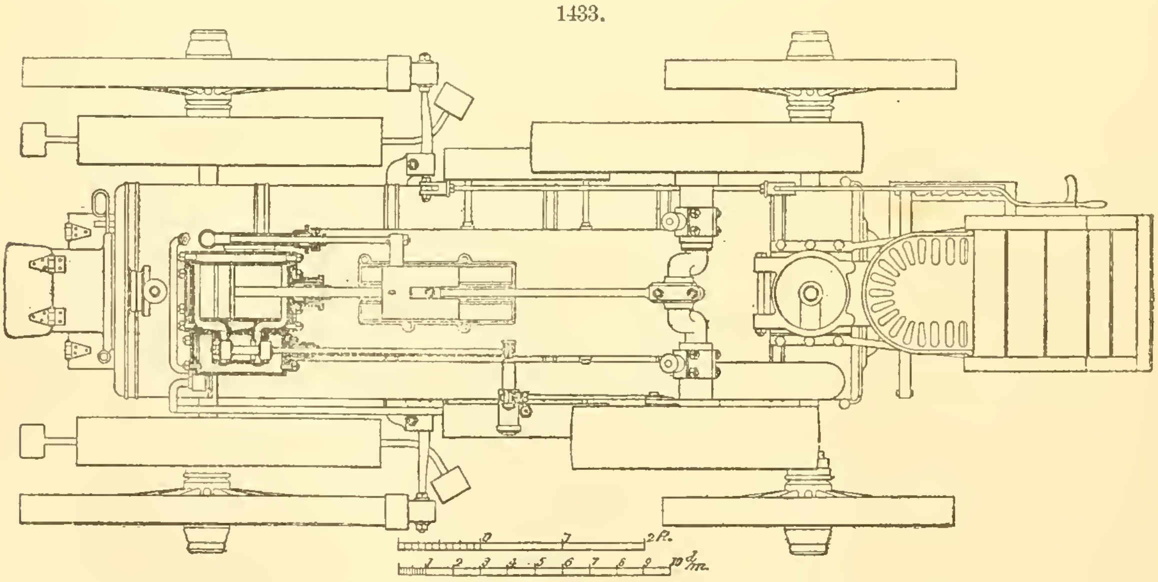
within the fire-box, at the sides, top, and back. Each set of pipes is the same, as follows: The lower horizontal pipe, $1\frac{1}{4}$ inch in diameter, forms the grate-bar, and is connected to the front fire-box sheet by a union attachment; the back end of this pipe is joined to two vertical pipes leading upward, and to a third pipe which is turned down and provided with a blow-off cock. The other ends

1432.



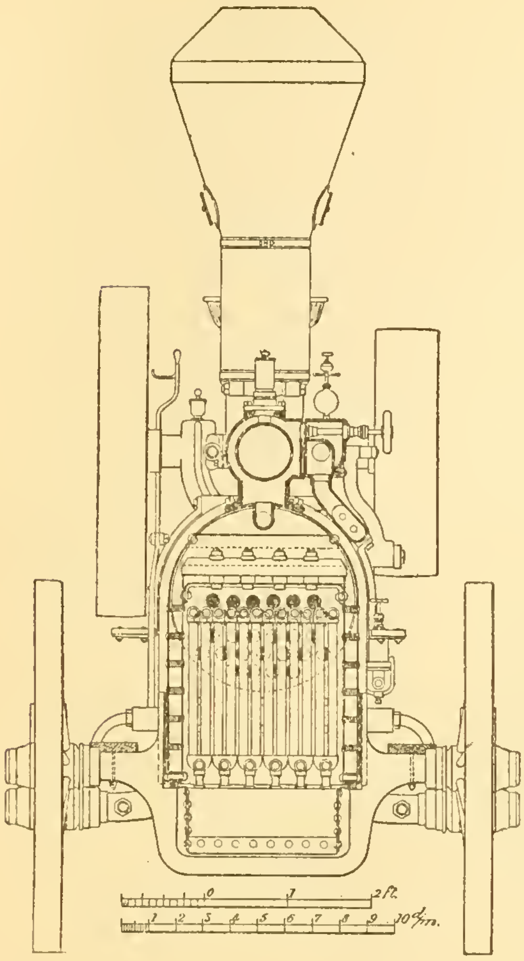
of the first-named pipes connect with two horizontal pipes which unite near the front fire-box sheet, and are connected to that sheet. Thus these series of pipes form a grate with air-spaces of $2\frac{1}{4}$ inches, and the spaces of half an inch between the vertical pipes allow sufficient opening for the passage of flame, but do not permit the straw to go through unconsumed, and thus prevent the obstruction of the tube with soot, etc. These pipes are also a valuable addition to the most effi-

1433.

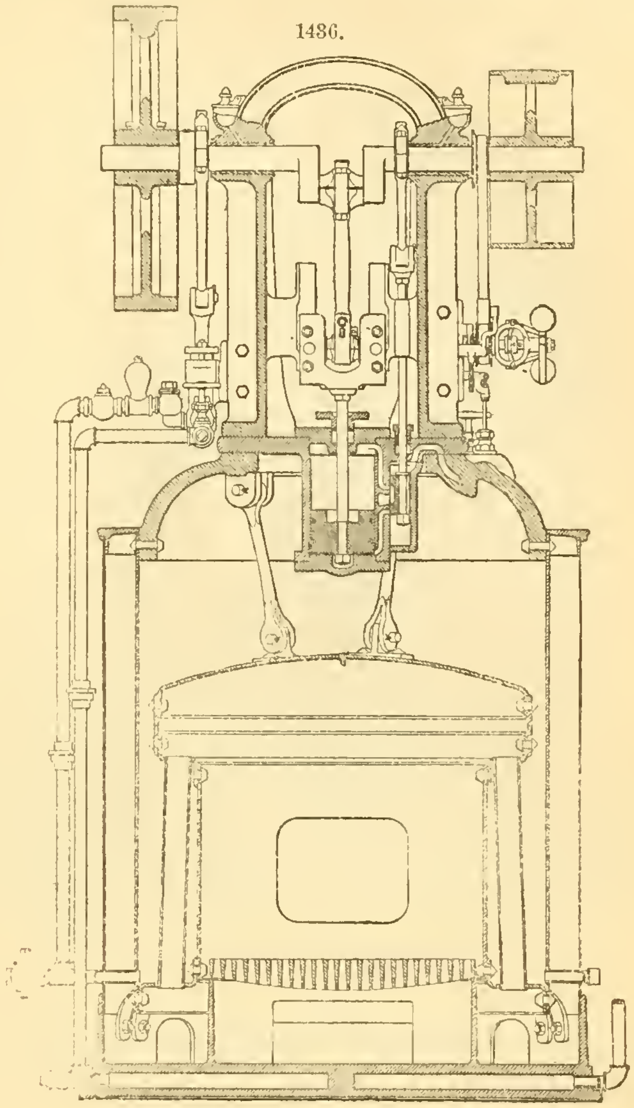


cient portion of the heating surface, nearly doubling the heating surface of the fire-box. The straw is fed into the furnace through a funnel-shaped mouth-piece, having a door hinged at the top, which is generally left open when feeding, care being taken to keep the funnel stuffed with straw. There are minute peep-holes for showing the condition of the fire; and if flame is not seen in the

1434.

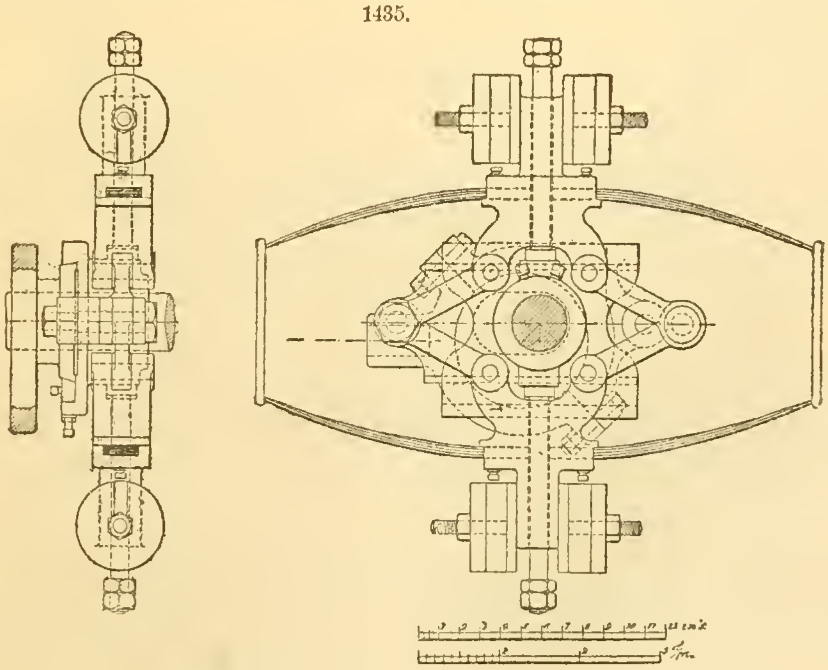


1436.



furnace, the feeding should be stopped for a while. The ash-pan can be readily removed, to give access to the pipes. It is flanged around the bottom, so as to hold water for extinguishing the sparks that fall into it.

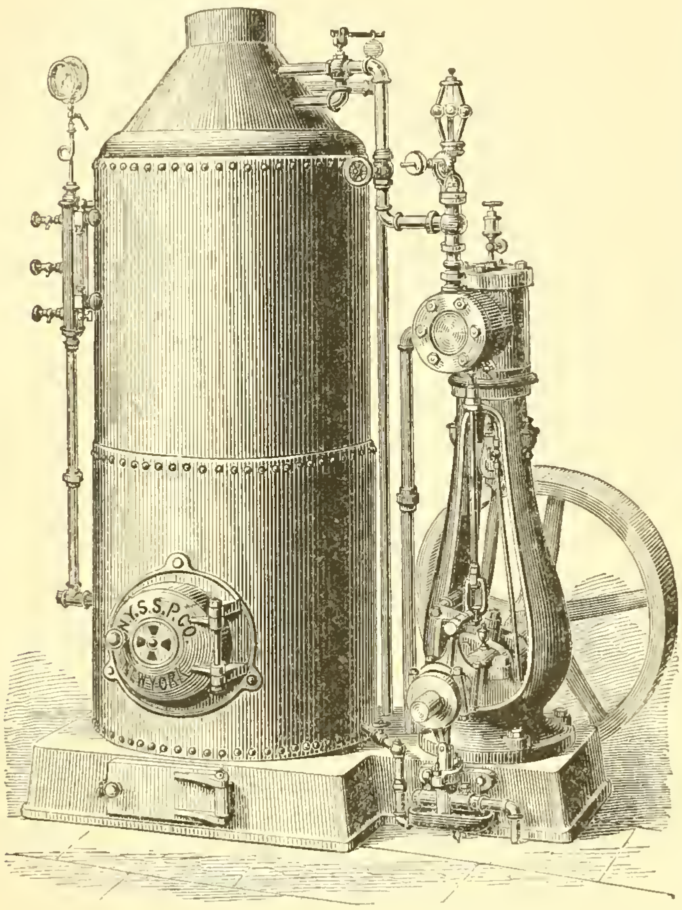
1435.



The boiler attachments consist of a safety-valve, of the variety known as pop-valves, similar to the one shown in Fig. 417, in the article BOILERS, STEAM; a glass water-gauge; two gauge-cocks, the lower one being placed at the proper working level; steam-gauge; and whistle.

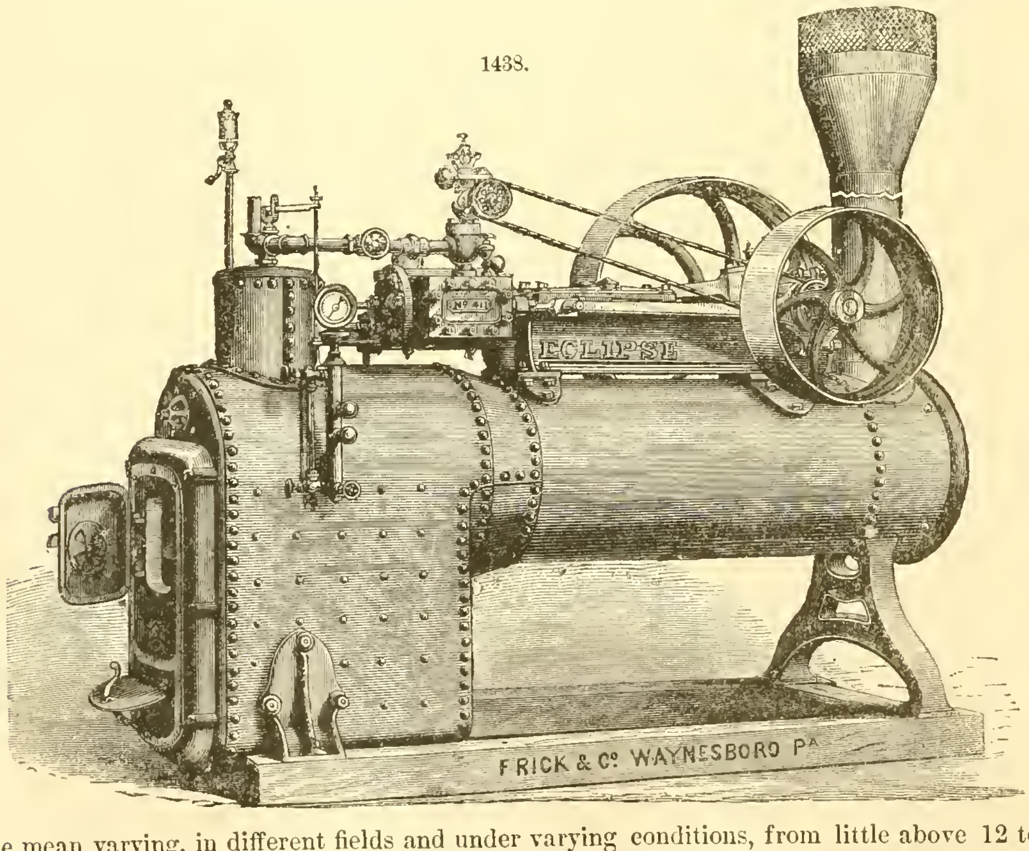
In localities where straw is used as fuel, its value is generally very little; but it is still desirable to use it in an economical apparatus, for the purpose of reducing the weight and size of the boiler, lessening the labor of firing, and reducing the consumption of water (which often has to be hauled from a distance) to a minimum. In the engine under consideration, the boiler is protected from loss of heat by radiation, and the engine is constructed with features which are believed by the maker to be favorable to economical working. The cylinder is surrounded by a casing which communicates directly with the steam-space of the boiler. The steam-valve consists of two solid pistons connected by a stem, and the valve-chest is surrounded by a steam-jacket, as shown in Figs. 1433 and 1434. The valve is moved by an eccentric, which is connected to a centrifugal governor on the crank-shaft (see Fig. 1435), in such a manner that its throw and angular advance are both varied with a variation in the position of the governor-arms due to a change of speed. The effect of this arrangement is to change the point of cut-off in accordance with a change of resistance, always admitting steam at a pressure nearly equal to that in the boiler, and preserving the steam-lead constant at all points of cut-off.

1437.



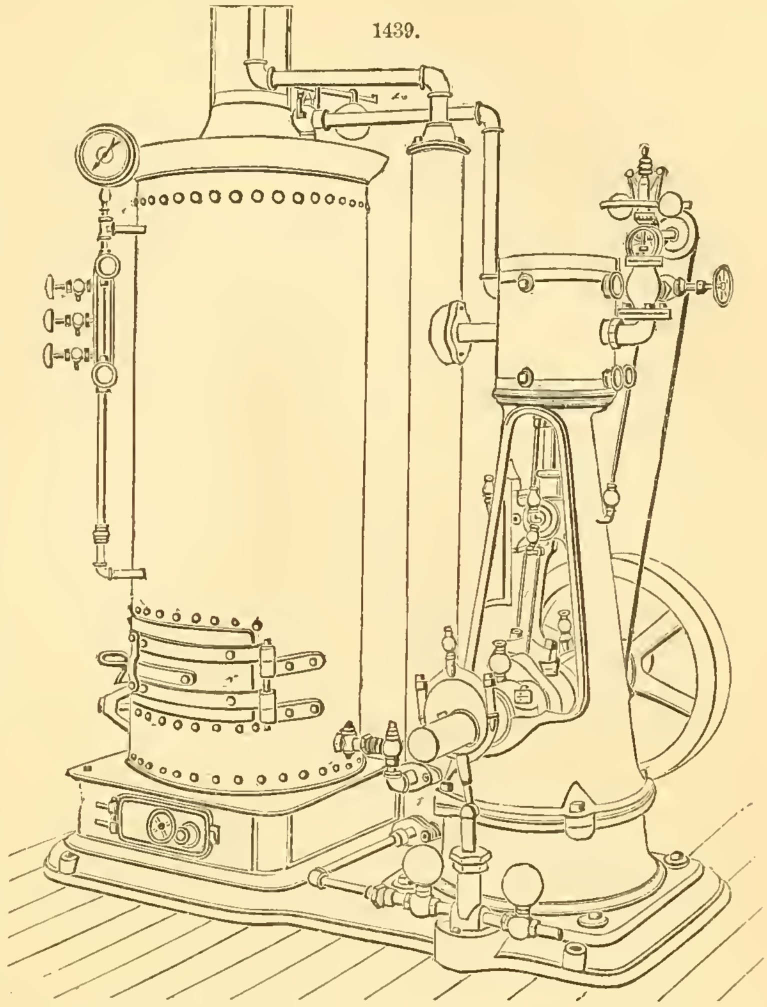

Mr. Hoadley has kindly furnished some particulars of his experience with this engine in California, when driving threshing machines. He says: "The power required to drive a large, 40-inch separator, with feed apron and elevator to conduct the unthreshed grain to the beating cylinder, threshing and cleaning 800 to 1,200 sacks in a summer day (usually about 10 hours actual running time), say 180 to 270 bushels per hour, varies from 12 to 30 indicated horse-power; these variations being encountered in the same field, often in the same stack, on account of irregularity of feeding,

1438.



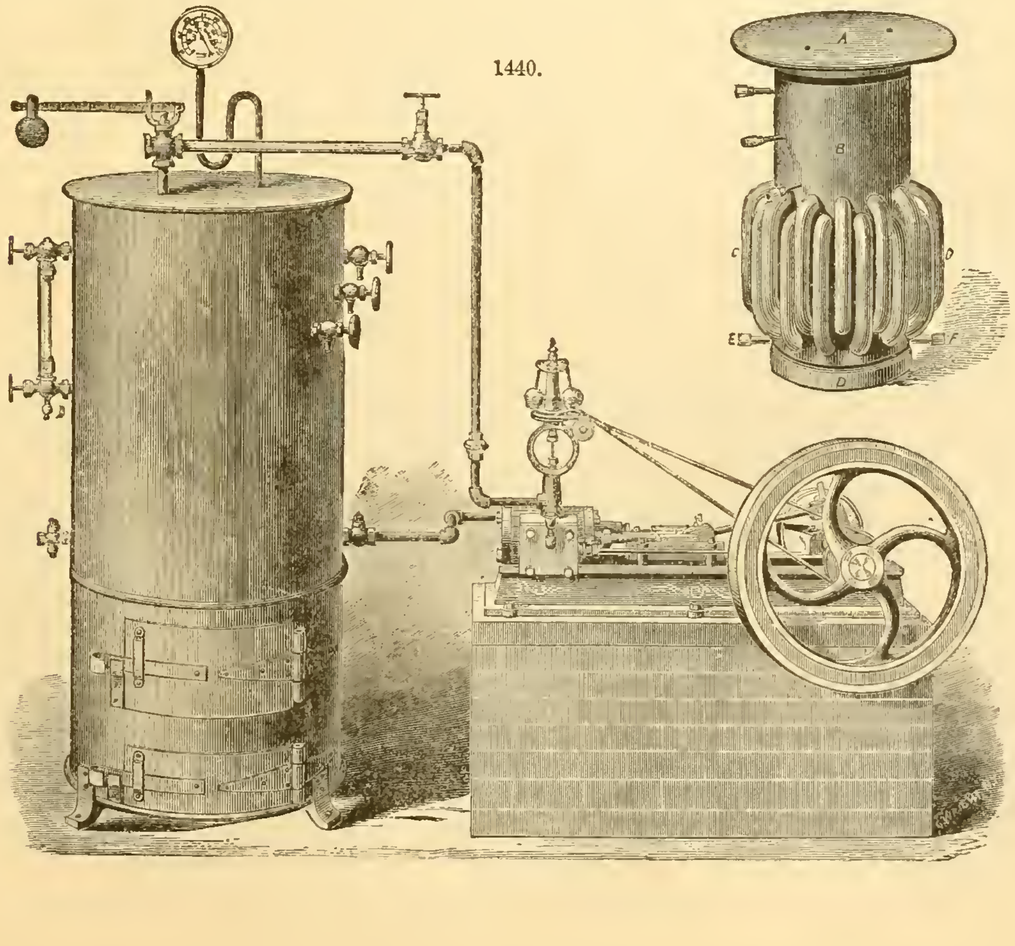

and the mean varying, in different fields and under varying conditions, from little above 12 to little under 20 horse-power. Occasionally even more power is called for, 30, 40, 45 horse-power—far more than the boiler could maintain, but exerted by the engine for a few moments; and still more

rarely the long, heavy, tightly-strained belt, unable to transmit all the power the engine can supply and the separator demands, is thrown off or pulled in two. The boiler was found capable of supplying all necessary steam, for a mean of 20 horse-power, at the rate of 30 lbs. of water per horse-power per hour = 70 to 75 gallons per hour. Very heavy threshing, in good grain, was done with 46 to 60 gallons per hour (temperature 73° F., weight 8⅓ lbs. per gallon); and this rate of evaporation, yielding 12 to 18 horse-power, was maintained with great ease, with most moderate firing. The quantity of straw consumed is really inconsiderable, being no more, in general, than one-thirtieth to one-fiftieth of the whole straw and chaff ejected from the separator, the grain being cut with the header. One man finds it easy to do firing as well as all the work of an 'engineer,' and is less tired at night than when firing with wood."


1439.

Below will be found a summary of the results obtained from a test of one of these engines, of the size referred to in the preceding remarks: Diameter of cylinder, 7½ inches. Stroke of piston, 10 inches. Duration of trial, 2½ hours. Average revolutions of engine per minute, 236.7. Average net horse-power, measured on friction-brake, 15.53. Pounds of water evaporated per hour, 648.4 Pounds of straw burned per hour, 351.6. Pounds of straw per net horse-power per hour, 22.64. Pounds of water evaporated per pound of straw, 1.84.

Semi-portable Engines, intended for places where light power is needed, usually have vertical


1440.

*Dimensions of Portable and Semi-portable Engines.*

| No. | DETAILS. | J. C. Hoadley Company. | Fitchburg Steam Engine Co. | Erie City Iron Works. | Baxter. |
|---|---|---|---|---|---|
| 1 | Boiler horizontal or vertical | Horizontal. | Vertical. | Horizontal. | Vertical. |
| 2 | Length or height of boiler, ft | 9.125 | 7 | 11.5 | 4.25 |
| 3 | Diameter of shell, in | 27 | 36 | 30 | 32 |
| 4 | Length of furnace, in | 36.5 | 30 diam. | 38 | 22 diam. |
| 5 | Width " " | 23 | ........ | 24 | ..... .... |
| 6 | Height " " | 28.875 | 30 | 36 | 23 |
| 7 | Grate surface, sq. ft | 5.75 | 4.59 | 6.32 | 2.5 |
| 8 | Thickness of shell, in | .25 | .25 | .25 | .26 |
| 9 | " of crown-sheet, in | .25 | .3125 | .3125 | .3125 |
| 10 | " of tube-heads, in | .375 | .3125 | .375 | .3125 |
| 11 | Diameter of stay-bolts, in | .875 | .75 | .875 | .......... |
| 12 | Distance between centres of stay-bolts, in | 4.5 | 10 | 5.5 | .......... |
| 13 | Number of tubes | 29 | 52 | 22 | 24 |
| 14 | External diameter of tubes, in | 2.25 | 2.25 | 3 | 2 |
| 15 | Length of tubes, in | 54 | 54 | 78 | 18 |
| 16 | Tube calorimeter, sq. ft | .671 | 1.2 | .929 | .429 |
| 17 | Heating surface in fire-box, sq. ft | 28 | 24.5 | 30 | .......... |
| 18 | Total heating surface, sq. ft | 108 | 156 | 120 | 58 |
| 19 | Draught area through ash-pit doors, sq. ft | 1.28 | .486 | .59 | .......... |
| 20 | " " " grate bars, sq. ft | 1.92 | 2.43 | .......... | .......... |
| 21 | " " " holes in furnace door, sq. in | 0 | 0 | .......... | .......... |
| 22 | Cross-section of chimney, sq. ft | .545 | .55 | 1.07 | .349 |
| 23 | Ratio of heating to grate surface | 18.8 | 34 | 19 | 23.2 |
| 24 | " of tube calorimeter to grate surface | .117 | .261 | .169 | .172 |
| 25 | Water space, cub. ft | 11.2 | 18 | .......... | 5.25 |
| 26 | Steam " " | 7.5 | 11 | .......... | 5.1 |
| 27 | Diameter of feed-pipe, in | .75 | 1 | 1 | 1 |
| 28 | " of blow-off pipe, in | 1 | 1 | 1.5 | .75 |
| 29 | " of steam-pipe, in | 1.5 | 1.5 | 1.5 | .......... |
| 30 | " of safety-valve, in | 2 | 1.5 | 2 | 1 |
| 31 | " of exhaust-nozzle, in | 2 | 2 | .......... | .75 |
| 32 | Engine horizontal or vertical | Horizontal. | Vertical. | Horizontal. | Vertical. |
| 33 | " attached to boiler or independent | Attached. | Ind't. | Attached. | Attached. |
| 34 | Arrangement of cut-off | Controlled by gov. | Fixed. | Fixed. | Fixed. |
| 35 | Diameter of cylinder, in | 7.5 | 7 | 7 | 5 |
| 36 | Length of stroke, in | 10 | 7 | 10 | 5 |
| 37 | Area of steam-port, sq. in | 3.93 | 3.5 | 4 | 1 |
| 38 | " of exhaust-port, sq. in | 4.13 | 3.5 | 7.625 | 1.75 |
| 39 | Clearance in per cent. of piston displacement | 10 | 8 | 6.25 | 6.6 |
| 40 | Kind of valve | Piston. | Piston. | Slide. | Slide. |
| 41 | Diameter of valve-stem, in | .625 | .5 | .151 | .625 |
| 42 | Stroke of valve, in | $1\frac{1}{16}$ to $2\frac{15}{16}$ | 2.5 | 2.25 | 1 |
| 43 | Diameter of piston-rod, in | 1.25 | 1.375 | 1.1875 | .875 |
| 44 | " of exhaust-pipe, in | 2 × 2 | 2 | 2 | 1.5 |
| 45 | " of feed-pump, in | .875 | 1.75 | 1.125 | 1 |
| 46 | Stroke " " " | 10 | 3 | 10 | 1.5 |
| 47 | Number of fly-wheels | 2 | 1 | 2 | 2 |
| 48 | Diameter " " in | 36 and 48. | 42 | 30 and 44 | 24 and 14 |
| 49 | Face " " in | 9 and 7. | 8 | 8.5 and 10.5 | 6.5 and 5 |
| 50 | Weight " " lbs | 150 each. | 650 | 120 and 350 | 48 and 160 |
| 51 | Diameter of truck wheels, in | 42 and 54. | ........ | 44 and 54 | .......... |
| 52 | Weight, light, lbs | 7505 | 5480 | 6000 | 3100 |
| 53 | " with water and coal, lbs | 8202 | 6600 | 6500 | 3400 |
| 54 | Length, in | 125 | 84 | 144 | 42 |
| 55 | Width, in | 72 | 48 | 72 | 42 |
| 56 | Height, in | 101 | 114 | 90 | 90 |
| 57 | Working pressure, lbs. per sq. in | 120 | 60 | .......... | 70 |
| 58 | Revolutions per minute | 240 | 220 | 175 | 240 |
| 59 | Cut-off, from commencement of stroke, in | 1.7 | 4.3 | .......... | 3.5 |
| 60 | Effective horse-power | 18 | 14.5 | 10 | 6 |

tubular boilers, and engines, either vertical or horizontal, attached to the casting on which the boiler rests, but not connected to the boiler, except by the steam-pipe. In some instances, however, as in the case of *the Baxter engine*, Fig. 1436, and some other varieties, the engine is attached to the boiler. In the Baxter engine, the cylinder is secured in the steam-space of the boiler. The illustration of this well-known engine is so complete as to need no further description.

The semi-portable engine manufactured by the New York Safety Steam-Power Company, Fig. 1437, is a good example of the most ordinary variety of this class—an example that has been copied, with more or less success, by many other builders.

*The Eclipse Semi-Portable Engine*, Fig. 1438.—The frame or bed comprises the one cylinder-head, guides for cross-head, and the two bearings for crank-shaft, all in one solid casting, the object being to prevent the working parts of the engine from getting out of line. The shape of this bed is the half of a hollow cylinder, except a small portion of one end, which is an entire hollow cylinder, with its one end closed by the formation of a flange or cylinder-head, to which are bolted the cylinder and steam-chest, which is also one solid casting. All the exposed parts of the cylinder are jacketed to prevent loss of heat by radiation. By this plan of constructing the bed-plate the working strain is directly through the centre of cylinder and pillow-blocks, thereby making a very strong engine with little material. The heater is formed by a separate cast-iron pipe bolted near its one end to the steam-cylinder, and supported at the other end by a bracket over the bed-plate. The

*Dimensions of Portable and Semi-portable Engines (continued).*

| Whitman & Burrell. | Gaar, Scott & Co. | Sample, McElroy & Co. | New York Safety Steam Power Co. | Lane & Bodley. | Niles Tool Works. | Emory W. Mills. | Snyder's Little Giant. | No. |
|---|---|---|---|---|---|---|---|---|
| Horizontal. | Horizontal. | Vertical. | Vertical. | Horizontal. | Vertical. | Horizontal. | Vertical. | 1 |
| 8.5 | 8.42 | 5.5 | 6.25 | 8.56 | 5 | 9.17 | 4 | 2 |
| 30 | 27.5 | 28 | 35 | 28 | 30 | 19 | 10 | 3 |
| 30 | 32 | 25 diam. | 30 diam. | 37 | 25.5diam. | 16 | 15 diam. | 4 |
| 24 | 23.5 | ........ | ........ | 17.75 | .......... | 27.5 | .......... | 5 |
| 20 | 34 | 30 | 21 | 28.75 | 22 | 27 | .......... | 6 |
| 5 | 5.29 | 3.4 | 4.9 | 4.56 | 3.48 | 3 | .917 | 7 |
| .25 | .25 | 25 | .3125 | .25 | .25 | .25 | .3125 | 8 |
| .3125 | .3125 | .375 | .375 | .25 | .3125 | .25 | .375 | 9 |
| .3125 | .375 | .375 | .375 | .3125 | .3125 | .3125 | .......... | 10 |
| .625 | .875 | .875 | .75 | .75 | .......... | .75 | .......... | 11 |
| 6 | 5 | 9 | 9 | 6.75 × 5.5 | .......... | 3.5 | .......... | 12 |
| 15 | 27 | 37 | 64 | 30 | 40 | 31 | 32 | 13 |
| 3 | 2.5 | 2 | 2 | 2.25 | 2.75 | 1.5 | 1.0625 | 14 |
| 89 | 54 | 36 | 48 | 49.625 | 30 | 66 | 16 | 15 |
| .633 | .767 | .661 | 1.144 | .694 | 1.4 | .301 | .......... | 16 |
| 10 | 20 | 17.2 | 19.2 | 24.3 | 13.9 | 18 | .......... | 17 |
| 120 | 85.7 | 69.5 | 153.1 | 95.1 | 82.6 | 86 | 14 | 18 |
| .521 | .563 | .375 | 1.24 | 1.24 | .66 | 1 | .122 | 19 |
| 1.77 | 1.85 | .792 | 2.45 | 1.86 | 1.16 | 1.56 | .458 | 20 |
| 0 | 4 | 0 | 4 | 2.2 | 0 | 0 | 0 | 21 |
| .417 | .545 | .785 | .78 | .327 | .54 | .087 | .165 | 22 |
| 24 | 16.2 | 20.4 | 31.1 | 20.8 | 23.4 | 28.7 | 15.3 | 23 |
| .127 | .145 | .194 | .234 | .152 | .402 | .1 | .......... | 24 |
| 15.125 | 15.97 | 7.25 | 19.53 | 17.58 | 6.29 | 8 | .902 | 25 |
| 8.75 | 7.27 | 5.2 | 2.68 | 6.67 | 3.78 | 4 | .455 | 26 |
| 1 | .75 | .75 | .75 | 1 | .5 | 1 | .375 | 27 |
| 1 | 1.5 | 1.5 | 1.25 | 1 | .75 | 1 | .375 | 28 |
| 1.25 | 1.5 | 1.25 | 1.25 | 2 | 1.25 | 1.75 | .5 | 29 |
| 1.25 | 1.5 | 1.5 | 2 | 1.5 | 2.5 | 1.25 | .5 | 30 |
| 1.5 | 1.125 | 1 | 1.5 | .75 | 1.25 | 1.25 | .75 | 31 |
| Horizontal. | Horizontal. | Vertical. | Vertical. | Horizontal. | Horizontal. | Horizontal. | Horizontal. | 32 |
| Attached. | Attached. | Ind't. | Ind't. | Attached. | Ind't. | Attached. | Ind't. | 33 |
| Adjustable. | Fixed. | Fixed. | Fixed. | Fixed. | Fixed. | Controlled by gov. | Fixed. | 34 |
| 7 | 6.5 | 5 | 7 | 7 | 5 | 6 | 2.75 | 35 |
| 10 | 13 | 6 | 9 | 12 | 7 | 6 | 4.5 | 36 |
| 3.75 | 3 | 2.5 | 3.125 | 3.62 | 1.25 | 4.1 | .475 | 37 |
| 15 | 6.5 | 5 | 5 | 6.87 | 2 | 11 | .689 | 38 |
| 9 | 9.23 | 19.5 | 6.86 | 9.07 | 3.86 | 11.75 | .767 | 39 |
| Slide. | Slide. | Slide. | Slide. | Slide. | Slide. | Piston. | Slide. | 40 |
| .9375 | .875 | .5625 | .75 | .9375 | .625 | .5 | .5 | 41 |
| .......... | 2.25 | 1.75 | 2.5 | 1.875 | 1.25 | 3.5 max. | .625 | 42 |
| 1.0625 | 1.25 | .9375 | 2.125 | 1.3125 | 1 | 1 | .875 | 43 |
| 1.5 | 2 | 2 | 1.5 | 1.8125 | 1.5 | 2 | .......... | 44 |
| 2 | .75 | 1.625 | 1.75 | .75 | 1.75 | 1.625 | 1 | 45 |
| .......... | 13 | 3 | 2.5 | 12 | 1.5 | 1 | .......... | 46 |
| 1 | 1 | 1 | 1 | 2 | 1 | 1 | 2 | 47 |
| 48 | 42 | 26 | 42 | 40 & 15.9375 | 24 | 36 | 16 and 6 | 48 |
| 8.25 | 8 | 6.5 | 7.5 | 7.875 & 4.375 | 6.5 | 6 | 1.75 and 2 | 49 |
| 320 | 370 | 200 | 565 | 345 and 85 | 238 | 260 | 35 | 50 |
| 36 and 48 | 40 and 48 | ........ | ........ | 3.3125 and 41 | .......... | 39 and 43 | .......... | 51 |
| 4800 | 5225 | 2400 | 3542 | 5514 | 2700 | 4250 | 535 | 52 |
| 5560 | 6110 | 2900 | 4802 | 6600 | 3200 | 4850 | 630 | 53 |
| 126 | 127 | 55 | 77 | 148 | 54 | 129 | 50 | 54 |
| 69 | 78 | 36 | 42 | 79.5 | 34 | 62.5 | 54 | 55 |
| 108 | 84 | 87 | 126 | 80.5 | 65.5 | 86 | 48 | 56 |
| 75 | 60 | 100 | 45 | 75 | 60 | 100 | 60 | 57 |
| 140 | 190 | 400 | 160 | 200 | 225 | 250 | 300 | 58 |
| 5.25 | 8.67 | 3.5 | 5.25 | 4.9 | 5.25 | 4.5 | 1.38 | 59 |
| 12 | 10 | 6 | 10 | 15 | 7 | 10 | 1 | 60 |

water-pipe passes several times through this heater, and is of sufficient length to heat the water nearly to the boiling-point before it enters the boiler. The boiler is of the locomotive pattern, with the water-space extending entirely around the bottom, forming a mud drum. The boiler-front is made of cast-iron in sections, and so arranged that the draught in passing to the furnace passes over the inside lining of the front, thereby keeping it cool and less liable to crack or burn out. The machine can very easily be dismounted from the boiler and used as a stationary engine.

*The Haskins Engine*, Fig. 1439, is selected as an example of a class of engines that have been received with considerable favor, for powers of from 10 to 50 horse-power.

*The Little Giant Engine*, Fig. 1440.—The chief peculiarity of this machine, which is constructed of from 1 horse-power up, is the boiler. The body is made of tubing 10 inches in diameter, and is closed below with a cast-iron cap *D*, and above by the head *A*; 29 water-tubes *C*, 15 inches long, project into the fire. The couplings *E* and *F* are for connecting the feed and blow-off pipes. The engine is of the ordinary horizontal form, with plain slide-valve.

*Data of Portable and Semi-portable Engines.*—The particulars in the preceding table are both interesting and valuable, as representing the practice of some of the most experienced engine-builders in this country. The data have in all cases been furnished by the manufacturers, and are therefore very reliable.

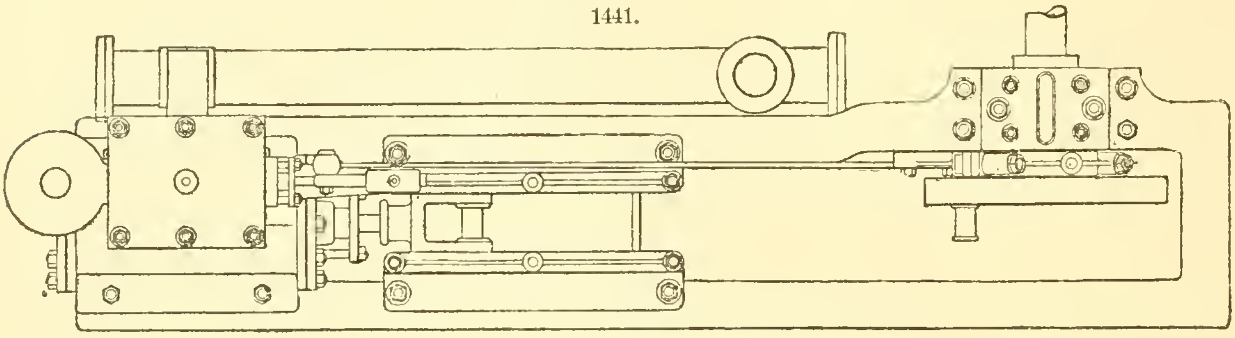
For works of reference, see ENGINES, HEAT.

R. H. B.

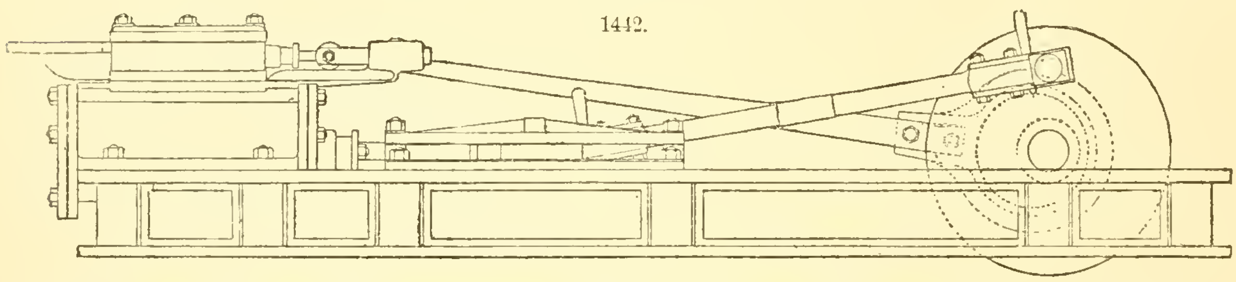
ENGINES, STEAM, STATIONARY (RECIPROCATING). Under this head are included engines resting on foundations of brick or stone, to which they are secured by bolts. A stationary steam-engine, in distinction from a portable or semi-portable engine, is unconnected with the boiler which furnishes it with steam, with the exception of the steam-pipe connection; and it is not uncommon, in the case of large stationary engines, for one manufacturer to furnish the engine and another the boiler. Such engines may be either condensing or non-condensing, but the majority of stationary engines used in the United States do not have condensers.

A horizontal engine, with plain slide-valve, the speed being controlled by the action of the governor on the throttle-valve, probably represents the most common type of stationary engine that has been and is still used in this country. A good example of this form of engine, as built by Lane & Bodley, is shown in Figs. 1441 and 1442. At the side of the engine frame, in Fig. 1441, is the feed-water heater, containing a coil of tubes through which the feed-water circulates, and around which

1441.



1442.



the exhaust-steam passes before being discharged into the atmosphere. The action of the governor in such an engine is, of course, to reduce the pressure of the steam admitted into the cylinder, whenever the speed of the engine tends to increase in consequence of the reduction of the load; or, in other words, to reduce the mean pressure in the cylinder by throttling or wiredrawing the steam. Where the load on an engine is practically constant, there is no particular objection to this arrangement, if the point of cut-off is so adjusted as to give the most economical result. But when the load varies greatly, there will obviously be a frequent reduction in the boiler pressure before its admission into the cylinder, with the consequent objection of subjecting the boiler to a considerable strain, without the resulting advantages of the high pressure produced. For this reason, many manufacturers have designed what are known as automatic cut-off engines, in which the governor controls the cut-off mechanism, and varies the mean pressure in the cylinder by changing the point of cut-off, while the initial pressure of the steam is unaltered. As ordinarily constructed, such arrangements are also more sensitive than the regulation by throttle, so that the variation of speed under varying load is much less. This is not a necessary distinction between the two methods of regulation, but it is one that usually obtains in practice. An automatic cut-off engine, also, is usually designed with greater attention to the distribution of steam, and frequently with many improvements in workmanship and minor details; so that it is almost invariably more economical than an engine regulated by throttle, under circumstances otherwise similar. It is doubtful if this is necessarily the case; that is, whether if the latter form of engine were as carefully designed as the other, it would not be about as economical. In practice, however, as already remarked, the automatic cut-off engine is generally superior to its rival, both in regard to its capacity for controlling the speed, and in economical performance. Until a recent period, the engine regulated by throttle possessed the advantages of cheapness and simplicity; but, with improved methods of construction, it is believed that at present the difference in first cost is almost the only advantage it can claim.

The best point of cut-off, under given conditions, has not been ascertained with precision; but for average conditions, with from 60 to 80 lbs. steam-pressure, it is probably between one-third and one-half stroke. The cut-off can be shortened considerably without much change in the economy; but, of course, the shorter the cut-off, the larger will be the cylinder that is required for a given power; and the most economical engine, all things considered, is the one that gives the most power for about the minimum number of pounds of steam per horse-power per hour. A series of experiments to determine the best point of cut-off for various sizes of cylinders, and different steam-pressures and piston-speeds, would be of immense advantage to all who are engaged in the designing and construction of engines. The most extensive tests ever conducted in relation to this matter were the U. S. Government expansion experiments, which were undertaken to settle some controverted questions in regard to the benefits to be derived from expansion. These experiments were never completed so as to include a high range of steam-pressures and piston-speeds; but there were several series, under

certain conditions, that are quite complete. Their results have never before been made public; but, by the kindness of Chief Engineer B. F. Isherwood, a summary of results has been made up from the official records, and is given in the following table and in that on pages 684 and 685. They are worthy of the careful attention of all who are interested in the subject.

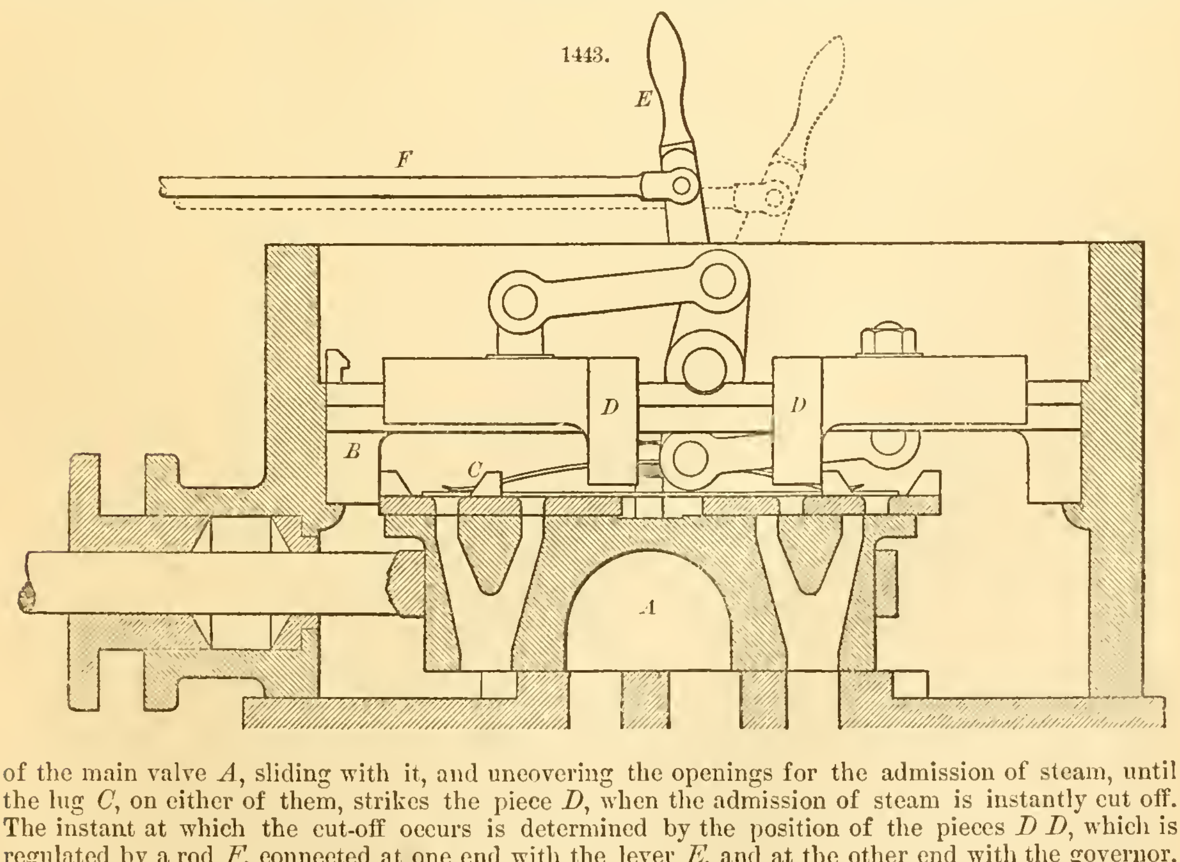
*Principal Dimensions of Cylinders used in U. S. Expansion Experiments.*

| NUMBER OF CYLINDER. | Diameter. | Stroke. | Clearances. | Diameter of Piston-rod. | Net Displacement of Piston per Stroke. | Friction Pressure. |
|---|---|---|---|---|---|---|
| | Inches. | Inches. | Cubic Inches. | Inches. | Cubic Inches. | Lbs. per Sq. In. |
| 1 | 12.26 | 20.08 | 291 | 2.5 | 2,272 | 5.1 |
| 2 | 12.26 | 20.08 | 283 | 2.48 | 2,274 | 5.1 |
| 3 | 12.4 | 20.08 | 250 | 2.48 | 2,328 | 5 1 |
| 4 | 12.4 | 20.08 | 268 | 2.48 | 2,328 | 5.1 |
| 5 | 13.77 | 20.08 | 499 | 2.5 | 2,892 | 3.1 |
| 6 | 13.77 | 20.08 | 476 | 2.48 | 2,893 | 3.1 |
| 7 | 15.66 | 20.08 | 1,350 | 2.5 | 3,769 | 3.0 |
| 8 | 15.67 | 20.08 | 1,279 | 2.48 | 3,776 | 3.0 |
| 9 | 21.52 | 20.08 | 724 | 2.5 | 7,205 | 2.4 |
| 10 | 21.52 | 20.08 | 1,066 | 2.48 | 7,206 | 2.4 |
| 11 | 30.02 | 20.08 | 2,619 | 5 | 13,818 | 1.5 |

The experiments detailed in these tables were made, for the most part, at the Novelty Iron Works in New York; and on their suspension, a supplementary series was conducted by the proprietors of those works, for the purpose of obtaining data for the construction of stationary engines. As the result of these experiments, a pamphlet was prepared, containing tables showing the various sizes of engines required for different horse-powers under varying conditions, and the effect on the economy of varying those conditions. This pamphlet was not issued at the time of its preparation, in consequence of the suspension of the works; but it has since been published, with additions, under the title of "Tables and Diagrams relating to Non-condensing Engines and Boilers," by W. P. Trowbridge (New York, 1872). The results of these tables are to be received, perhaps, with some caution; but they are much more accurate than the estimates of power and economy usually given in trade catalogues. A compilation made from this work, showing the sizes of engines especially recommended by the Novelty Iron Works for various powers, is given in the table on page 686, which will be found useful in practice.

The earliest form of cut-off introduced into this country, and in use on many engines at the present time, is believed to have been the one known as Boyden's cut-off, invented by that ingenious mechanic Seth Boyden, and illustrated in Fig. 1443. There are two cut-off valves, *B B*, on the back

1443.




of the main valve *A*, sliding with it, and uncovering the openings for the admission of steam, until the lug *C*, on either of them, strikes the piece *D*, when the admission of steam is instantly cut off. The instant at which the cut-off occurs is determined by the position of the pieces *D D*, which is regulated by a rod *F*, connected at one end with the lever *E*, and at the other end with the governor. As the cut-off valve must close while the steam-valve is opening, it is evident that this cut-off can only operate up to half stroke.

Fig. 1444 represents the variable expansion-gear of Gonzenbach. It consists of an ordinary short slide-valve and casing, with ports in the back, upon which another slide-valve and casing are im-

*Summary of U. S. Expansion Experiments made at New York*, 1865–1867.

| NUMBER FOR REFERENCE. | Duration of Experiment, in Hours. | Fraction of Stroke completed at Cut-off. | Revolutions per Minute. | PRESSURE IN POUNDS PER SQUARE INCH. | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | ABOVE THE ATMOSPHERE. | | | | Mean Back, above Zero. | Vacuum. | Mean Total. | Mean Indicated. | Mean Net. |
| | | | | Initial. | At Cut-off. | Terminal. | At End of Cushion. | | | | | |
| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 |
| 1 | 72 | .917 | 50.6 | 40.2 | 32.7 | 29.7 | 14.2 | 16 | non-con- | 53.5 | 37.5 | 32.4 |
| 2 | 96 | .913 | 50.6 | 39.8 | 33.7 | 30 | 13 | 15.9 | densing. | 53.4 | 37.5 | 32.4 |
| 3 | 96 | .863 | 50.8 | 25.5 | 22.8 | 17.7 | −8.1 | 4.1 | 10.7 | 39 | 34.9 | 29.8 |
| 4 | 72 | .862 | 51 | 28.9 | 18.3 | 13.9 | −8.9 | 3.6 | 11.1 | 36.3 | 32.7 | 27.6 |
| 5 | 72 | .861 | 48.9 | 9.5 | 7.7 | 4.2 | −8.5 | 4.5 | 10.2 | 23.3 | 18.8 | 13.7 |
| 6 | 72 | .855 | 49.5 | 4.4 | 2.8 | −0.1 | −8.4 | 3.9 | 10.7 | 18.2 | 14.3 | 9.2 |
| 7 | 48 | .791 | 47.8 | 45.7 | 38.8 | 29 | −7.9 | 2.7 | 12.1 | 57 | 54.3 | 49.2 |
| 8 | 48 | .7 | 49.3 | 45.2 | 38.7 | 24 | −7 | 3.6 | 11.2 | 54.6 | 51 | 45.5 |
| 9 | 48 | .6 | 48.1 | 44.8 | 37.8 | 18.7 | −7.3 | 2.5 | 12.3 | 51.6 | 48.8 | 43.7 |
| 10 | 20 | .6 | 49.3 | 45.3 | 38.7 | 18.3 | −7 | 3.3 | 11.4 | 51.3 | 48 | 42.9 |
| 11 | 48 | .5 | 48.2 | 44.6 | 37.3 | 13.5 | −7.6 | 2.5 | 12.2 | 47.4 | 44.9 | 39.8 |
| 12 | 48 | .409 | 48 | 44.5 | 38.1 | 9.2 | −7.3 | 2.2 | 12.4 | 43.1 | 40.9 | 35.8 |
| 13 | 48 | .301 | 49.4 | 44.2 | 38.6 | 4.7 | −8.4 | 2.1 | 12.5 | 37.5 | 35.4 | 30.3 |
| 14 | 48 | .203 | 47.5 | 44.5 | 39.6 | −0.2 | −8.4 | 2.1 | 12.6 | 30.8 | 28.2 | 23.1 |
| 15 | 48 | .292 | 51.2 | 44.6 | 39.5 | 4.5 | −6.9 | 2.4 | 12.1 | 37.4 | 35 | 29.9 |
| 16 | 48 | .2 | 50.7 | 44.8 | 39.3 | −0.1 | −7.5 | 2.4 | 12.4 | 30.8 | 28.4 | 23.3 |
| 17 | 48 | .204 | 49.2 | 44.7 | 41.2 | 0.5 | −9.1 | 1.9 | 12.6 | 31.1 | 29.2 | 24.1 |
| 18 | 48 | .054 | 46.7 | 44.3 | 40.6 | −6.6 | −8.6 | 2.4 | 12.4 | 16.8 | 14.4 | 9.3 |
| 19 | 48 | .1 | 49 | 44.9 | 41.3 | −4.7 | −9.4 | 1.9 | 12.7 | 21.5 | 19.6 | 14.5 |
| 20 | 72 | .792 | 51.4 | 39.2 | 28.3 | 20.2 | 16 | 16.7 | non-con- | 49.9 | 33.2 | 28.1 |
| 21 | 72 | .746 | 50.9 | 39.5 | 30.6 | 19 | 13.7 | 16.3 | densing. | 48.9 | 32.6 | 29.5 |
| 22 | 72 | .739 | 51.1 | 4.9 | 2.2 | −2.2 | −8.8 | 4.2 | 10.6 | 17.6 | 13.4 | 10.3 |
| 23 | 72 | .739 | 50.2 | 9.9 | 6.8 | 1 | −8.4 | 4.2 | 10.6 | 22.4 | 18.2 | 15.1 |
| 24 | 72 | .739 | 51 | 32.3 | 18.4 | 10.1 | −8.2 | 3.4 | 11.4 | 36.8 | 33.4 | 30.3 |
| 25 | 96 | .738 | 51 | 25.1 | 21.1 | 12 | −7.2 | 3.8 | 10.9 | 36.8 | 33 | 29.9 |
| 26 | 72 | .603 | 52.1 | 31.8 | 18.8 | 6.8 | −7.4 | 3.9 | 10.9 | 34.9 | 31 | 27.9 |
| 27 | 72 | .589 | 51.5 | 4.4 | 0.7 | −4.8 | −8.1 | 4 | 10.7 | 15.5 | 11.5 | 8.4 |
| 28 | 72 | .589 | 52.1 | 25.2 | 19.4 | 6 | −6.5 | 4.4 | 10.4 | 33.3 | 28.9 | 25.8 |
| 29 | 72 | .586 | 50.1 | 9.7 | 5.2 | −2.3 | −7.3 | 4.1 | 10.7 | 20.1 | 16 | 12.9 |
| 30 | 71 | .501 | 49.7 | 24.9 | 17.8 | 2.8 | −6.6 | 4 | 10.9 | 30.6 | 26.6 | 23.5 |
| 31 | 72 | .5 | 49.9 | 9.7 | 6.4 | −3.3 | −7 | 4.2 | 10.6 | 19.2 | 15 | 11.9 |
| 32 | 72 | ·5 | 50.1 | 29.1 | 16.6 | 2.3 | −6.8 | 4 | 10.9 | 30 | 26 | 22.9 |
| 33 | 72 | .498 | 49.9 | 24.4 | 17.7 | 2.7 | −6.6 | 3.7 | 11.1 | 30 | 26.3 | 23.2 |
| 34 | 72 | .487 | 50.2 | 4.3 | 0.8 | −5.9 | −7.7 | 3.9 | 10.7 | 14.3 | 10.4 | 7.3 |
| 35 | 72 | .747 | 50.8 | 24.4 | 18.7 | 11.9 | 7.5 | 15.4 | | 36.1 | 20.7 | 17.4 |
| 36 | 72 | .499 | 50 | 37.5 | 31.1 | 13.1 | 7.9 | 15.3 | non-con- | 42.8 | 27.5 | 24.5 |
| 37 | 72 | .243 | 50.4 | 56.8 | 52.4 | 10.6 | 8.5 | 15.4 | densing. | 45.6 | 30.2 | 27.2 |
| 38 | 72 | .122 | 50.4 | 63.8 | 80.2 | 9.8 | 9 | 15.1 | | 46.8 | 31.7 | 28.7 |
| 39 | 96 | .479 | 50.6 | 24.7 | 19.6 | 5.8 | −8.1 | 4 | 10.6 | 31.2 | 27.2 | 24.2 |
| 40 | 72 | .475 | 50.4 | 4 | 1.4 | −5 | −9.2 | 3.8 | 11 | 14.9 | 11.1 | 8.1 |
| 41 | 72 | .475 | 50.7 | 25.8 | 18.1 | 4.9 | −8.6 | 3.5 | 11.2 | 30.7 | 27.2 | 24.2 |
| 42 | 31 | .474 | 51.1 | 25.7 | 17.9 | 4.9 | −8.9 | 3.1 | 11.3 | 30.2 | 27.1 | 24.1 |
| 43 | 55 | .472 | 51.3 | 8.8 | 5.7 | −2.7 | −8.4 | 4.1 | 11 | 19 | 14.9 | 11.9 |
| 44 | 54 | .472 | 51.5 | 9.1 | 6.2 | −2.2 | −8.3 | 3.9 | 10.8 | 19 | 15.1 | 12.1 |
| 45 | 72 | .471 | 49.9 | 8.8 | 5.7 | −2.7 | −8.7 | 4 | 10.7 | 18.6 | 14.6 | 11.6 |
| 46 | 72 | .329 | 49.5 | 23.9 | 19.2 | 0.4 | −8.1 | 4.3 | 10.4 | 26.2 | 21.9 | 18.9 |
| 47 | 72 | .319 | 49.6 | 32.8 | 22.1 | 3 | 21 | 17 | non-con- | 30.3 | 13.3 | 10.9 |
| 48 | 29 | .292 | 48.6 | 37.7 | 29 | 3.8 | 22 | 16.5 | densing. | 32.5 | 16 | 13.6 |
| 49 | 43 | .187 | 53.2 | 35 | 28.3 | −4 | 4.2 | 5.4 | 9.4 | 24.1 | 18.7 | 16.3 |
| 50 | 96 | .256 | 51.5 | 23.5 | 16.9 | −5.1 | 0.5 | 4 | 10.7 | 20.5 | 16.5 | 14.1 |
| 51 | 24 | .255 | 51.4 | 23.4 | 17.6 | −4.3 | −1 | 3.6 | 11 | 20.6 | 17 | 14.6 |
| 52 | 72 | .25 | 49.9 | 8.1 | 4.2 | −8.4 | −3.7 | 4 | 10.7 | 12.6 | 8.6 | 6.2 |
| 53 | 63 | .25 | 53.1 | 23.7 | 17.3 | −4.9 | −9.3 | 4.4 | 10.4 | 22.2 | 17.8 | 15.4 |
| 54 | 72 | .247 | 48 | 3.4 | 0.4 | −9.2 | −4.5 | 4 | 10.8 | 10.3 | 6.3 | 8.9 |
| 55 | 72.1 | .239 | 50.6 | 21.4 | 16.7 | −5.2 | −0.5 | 4.3 | 10.4 | 19.8 | 15.5 | 13.1 |
| 56 | 72 | .237 | 49.7 | 7.6 | 4.1 | −8.4 | −3.2 | 4.2 | 10.6 | 12.3 | 8.1 | 5.7 |
| 57 | 96 | .237 | 51 | 21.4 | 16.7 | −5.2 | −0.8 | 4.4 | 10.4 | 19.9 | 15.5 | 13.1 |
| 58 | 72 | .228 | 50.9 | 2.7 | −0.1 | −9.7 | −5.2 | 3.6 | 11.1 | 9.5 | 5.9 | 3.5 |
| 59 | 72 | .123 | 51.2 | −0.6 | −2.7 | −10.5 | −8.7 | 3.4 | 11.4 | 6.7 | 3.3 | 1.8 |
| 60 | 96 | .116 | 51.6 | 15.7 | 12.7 | −7.8 | −7.4 | 3.7 | 11 | 12.6 | 8.9 | 7.4 |
| 61 | 72 | .11 | 49.9 | 4.7 | 2.4 | −9.7 | −7.7 | 3.5 | 11.2 | 8.4 | 4.9 | 3.4 |

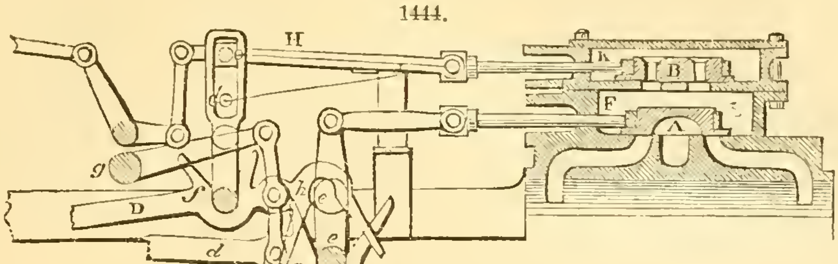
*Summary of U. S. Expansion Experiments made at New York*, 1865–1867 (*continued*).

| Horse-power. | | | Pounds of Water per Hour. | | | Temperature, in Fahrenheit Degrees. | | | Height of Barometer, in Inches. | Number of Cylinder. | Number for Reference. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Total. | Indicated. | Net. | Per Total Horse-power. | Per Indicated Horse-power. | Per Net Horse-power. | Air. | Feed. | Engine-room. | | | |
| 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 |
| 31.04 | 21.73 | 18.8 | 45.7 | 65.3 | 75.3 | 58.8 | 56.7 | 72.3 | 29.96 | 1 | 1 |
| 31.01 | 21.77 | 18.82 | 45.9 | 65.3 | 75.7 | 50.2 | 52.8 | 72.4 | 29.92 | | 2 |
| 22.78 | 20.37 | 17.88 | 46.3 | 51.7 | 60.6 | 37.8 | 36.6 | 58.2 | 30.2 | 2 | 3 |
| 21.3 | 19.18 | 16.17 | 46 | 51 | 60.5 | 37.8 | 38.1 | 66.3 | 29.96 | | 4 |
| 13.08 | 10.57 | 7.7 | 59.1 | 73.1 | 101 | 48.7 | 40.4 | 70.6 | 29.82 | | 5 |
| 10.37 | 8.13 | 5.23 | 64.2 | 82.2 | 128 | 49.9 | 43.1 | 71.3 | 29.81 | | 6 |
| 32.01 | 30.48 | 27.63 | 36.6 | 38.4 | 42.4 | 67.8 | 69 | 78.6 | 30.2 | 3 | 7 |
| 31.65 | 29.56 | 26.37 | 35 | 37.5 | 42 | 76.8 | 69 | 86.8 | 30.08 | | 8 |
| 29.01 | 27.61 | 24.72 | 33.8 | 35.5 | 39.7 | 62.8 | 68.1 | 78.8 | 30.01 | | 9 |
| 29.72 | 27.79 | 24.86 | 34.4 | 36.8 | 41.1 | 73.4 | 69 | 85.7 | 29.94 | | 10 |
| 26.8 | 25.4 | 22.54 | 33 | 34.9 | 39.2 | 61.2 | 67.8 | 77.9 | 29.94 | | 11 |
| 24.35 | 23.12 | 20.22 | 33 | 34.8 | 39.8 | 65 | 67.5 | 78 | 29.73 | | 12 |
| 21.75 | 20.54 | 17.59 | 31.9 | 33.9 | 39.5 | 64.8 | 65.8 | 82.5 | 29.73 | | 13 |
| 16.92 | 15.77 | 12.9 | 33.3 | 35.6 | 43.6 | 57.4 | 64.3 | 75.3 | 29.94 | | 14 |
| 22.52 | 21.05 | 17.99 | 30.2 | 32.2 | 37.7 | 56.5 | 58 | 80.1 | 29.62 | 4 | 15 |
| 18.37 | 16.92 | 13.89 | 30.9 | 33.7 | 40.9 | 50.9 | 60.3 | 79.2 | 30.32 | | 16 |
| 18.11 | 17 | 14.04 | 30.6 | 32.5 | 39.5 | 61.9 | 63 | 80.8 | 29.62 | | 17 |
| 9.19 | 7.89 | 5.11 | 38.5 | 44.9 | 69.2 | 59.8 | 62.5 | 81.3 | 30.07 | | 18 |
| 12.35 | 11.27 | 8.35 | 33.6 | 36.8 | 49.9 | 55.7 | 62.6 | 79.1 | 29.74 | | 19 |
| 37.47 | 24.92 | 21.1 | 38.9 | 58.5 | 69.1 | 73.4 | 68.3 | 80.7 | 30.25 | 5 | 20 |
| 36.35 | 24.21 | 21.95 | 38.2 | 57.4 | 63.4 | 71.8 | 60.2 | 80.6 | 30.5 | | 21 |
| 13.14 | 10.04 | 7.67 | 53.8 | 69.9 | 91.9 | 50.1 | 50.8 | 66.5 | 30.06 | 6 | 22 |
| 16.44 | 13.33 | 11.08 | 49.1 | 60.5 | 72.5 | 51.6 | 52.6 | 67 | 30.18 | | 23 |
| 27.4 | 24.86 | 22.56 | 40 | 44 | 48.5 | 49.9 | 57.2 | 67.4 | 30.2 | | 24 |
| 27.41 | 24.56 | 22.27 | 41.6 | 46.4 | 51.1 | 60.8 | 59 | 72.9 | 30.09 | | 25 |
| 26.55 | 23.57 | 21.22 | 38.5 | 43.4 | 48.3 | 28.3 | 40.6 | 57.4 | 30.03 | | 26 |
| 11.66 | 8.67 | 6.32 | 50.5 | 68.2 | 93.5 | 48 | 51.3 | 68.2 | 29.93 | | 27 |
| 25.33 | 21.98 | 19.62 | 39 | 44.8 | 50.8 | 48.6 | 45.3 | 69.5 | 30.16 | | 28 |
| 14.72 | 11.69 | 9.45 | 46.3 | 58.1 | 72 | 49.1 | 47.5 | 68.5 | 30.2 | | 29 |
| 22.23 | 19.29 | 17.07 | 39.4 | 45.3 | 51.1 | 26.6 | 38.6 | 57.5 | 30.27 | | 30 |
| 14.01 | 10.93 | 8.66 | 46.8 | 50.1 | 75.6 | 34.9 | 48.7 | 61.2 | 30.14 | | 31 |
| 21.96 | 19.05 | 16.76 | 39.1 | 45.1 | 51.3 | 25.5 | 35.1 | 60.1 | 30.18 | | 32 |
| 21.87 | 19.18 | 16.92 | 39.6 | 45.2 | 51.8 | 24.6 | 35.1 | 54.2 | 30.09 | | 33 |
| 10.49 | 7.62 | 5.36 | 49.2 | 67.8 | 96.5 | 47.4 | 51.3 | 68.9 | 29.8 | | 34 |
| 34.89 | 20.02 | 16.86 | 42 | 73.1 | 86.6 | 77.7 | 72.3 | 83.6 | 30.21 | 7 | 35 |
| 40.76 | 26.2 | 23.32 | 36.6 | 57 | 64.1 | 76.4 | 73.2 | 83.8 | 29.95 | | 36 |
| 43.73 | 28.99 | 26.07 | 32.5 | 48.9 | 54.3 | 70.8 | 75 | 80.8 | 30.07 | | 37 |
| 44.86 | 30.37 | 27.53 | 31.2 | 46 | 50.9 | 65 | 72.7 | 76 | 30.15 | | 38 |
| 30.13 | 26.24 | 23.37 | 39.2 | 45 | 50.4 | 29.3 | 35 | 68.7 | 30.03 | 8 | 39 |
| 14.36 | 10.68 | 7.78 | 46.4 | 62.4 | 85.9 | 35.4 | 36.7 | 63.9 | 30.31 | | 40 |
| 29.67 | 26.27 | 23.42 | 38 | 42.9 | 48.3 | 39.3 | 35.7 | 68.7 | 30.03 | | 41 |
| 29.43 | 26.37 | 23.46 | 38 | 42.3 | 47.5 | 39.2 | 35.8 | 66.8 | 29.48 | | 42 |
| 18.54 | 14.56 | 11.65 | 44.2 | 56 | 69.8 | 33 | 36 | 66.1 | 30.65 | | 43 |
| 18.63 | 14.81 | 11.88 | 43.9 | 55.2 | 68.7 | 37.9 | 36 | 66.9 | 29.85 | | 44 |
| 17.73 | 13.9 | 11.04 | 44.4 | 56.5 | 71.6 | 33.7 | 36.5 | 59.5 | 30.09 | | 45 |
| 24.66 | 20.64 | 17.85 | 40.2 | 48.2 | 55.4 | 35.1 | 36.7 | 63.7 | 29.85 | | 46 |
| 54.75 | 23.97 | 19.69 | 25 | 57.2 | 69.7 | 43.9 | 49.2 | 60.2 | 30.41 | 9 | 47 |
| 57.37 | 28.2 | 24.03 | 25 | 50.9 | 59.8 | 41.8 | 48 | 58.9 | 29.61 | | 48 |
| 46.65 | 36.24 | 31.56 | 33.5 | 43.2 | 49.5 | 84.5 | 69 | 86.4 | 30.5 | | 49 |
| 38.45 | 30.98 | 26.45 | 28.4 | 35.3 | 41.2 | 56.4 | 52.9 | 77.9 | 29.91 | 10 | 50 |
| 38.53 | 31.74 | 27.31 | 29.5 | 35.8 | 41.6 | 55 | 55 | 75.4 | 29.73 | | 51 |
| 22.74 | 15.55 | 11.27 | 33.3 | 48.4 | 66.8 | 50.1 | 52.6 | 73.6 | 29.94 | | 52 |
| 43.04 | 34.44 | 29.78 | 30.6 | 38.2 | 44.1 | 69.8 | 63.2 | 82.8 | 30.18 | | 53 |
| 17.96 | 10.93 | 6.81 | 34.7 | 57.3 | 91.6 | 48.4 | 52.1 | 69.3 | 30.18 | | 54 |
| 36.48 | 28.66 | 24.14 | 30.7 | 39 | 46.5 | 64.5 | 69.6 | 74.2 | 30.03 | | 55 |
| 22.24 | 14.61 | 10.31 | 32.8 | 49.9 | 70.8 | 63.8 | 70 | 70.8 | 30.19 | | 56 |
| 36.92 | 28.68 | 24.3 | 30 | 38.6 | 45.6 | 63.1 | 67.6 | 74.2 | 30.16 | | 57 |
| 17.61 | 10.95 | 6.49 | 84.8 | 54.9 | 94.4 | 72 | 71.3 | 78.9 | 29.93 | | 58 |
| 24.02 | 11.78 | 6.45 | 32.7 | 66.5 | 122 | 75.4 | 69.8 | 81.1 | 29.99 | 11 | 59 |
| 45.33 | 31.87 | 26.62 | 30.3 | 43 | 51.5 | 72.4 | 71.5 | 79.9 | 30 | | 60 |
| 29.26 | 17.06 | 11.84 | 32.5 | 55.7 | 80.8 | 66.6 | 70.1 | 75.3 | 29.9 | | 61 |

*Non-condensing Engines, 5 to 150 Horse-power.*

| Pressure above Atmosphere, in Pounds per Square Inch. | Cut-off, in Fraction of Stroke. | Revolutions per Minute. | POUNDS OF WATER PER HOUR. Per indicated Horse-power. | Per net Horse-power. | Revolutions per Minute. | POUNDS OF WATER PER HOUR. Per indicated Horse-power. | Per net Horse-power. | Revolutions per Minute. | POUNDS OF WATER PER HOUR. Per indicated Horse-power. | Per net Horse-power. | Revolutions per Minute. | POUNDS OF WATER PER HOUR. Per indicated Horse-power. | Per net Horse-power. | Revolutions per Minute. | POUNDS OF WATER PER HOUR. Per indicated Horse-power. | Per net Horse-power. | Revolutions per Minute. | POUNDS OF WATER PER HOUR. Per indicated Horse-power. | Per net Horse-power. | Revolutions per Minute. | POUNDS OF WATER PER HOUR. Per indicated Horse-power. | Per net Horse-power. | Revolutions per Minute. | POUNDS OF WATER PER HOUR. Per indicated Horse-power. | Per net Horse-power. | Revolutions per Minute. | POUNDS OF WATER PER HOUR. Per indicated Horse-power. | Per net Horse-power. | Revolutions per Minute. | POUNDS OF WATER PER HOUR. Per indicated Horse-power. | Per net Horse-power. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Net H. P. | | 5 | | | | | | 10 | | | | | | 15 | | | | | | 20 | | | | | | 25 | | | | | |
| Diameter × stroke, in in. | | 5 × 12 | | | 5 × 9 | | | 6 × 16 | | | 6 × 9 | | | 7 × 20 | | | 7 × 12 | | | 8 × 20 | | | 8 × 12 | | | 9 × 24 | | | 9 × 15 | | |
| 100 | 1/4 | 95 | 30.4 | 38 | 129 | 28.9 | 36.6 | 100 | 29 | 36.2 | 179 | 26.7 | 33.8 | 87 | 29 | 35.8 | 145 | 27.1 | 33.9 | 88 | 28.3 | 35 | 149 | 26.7 | 33.4 | 72 | 28.5 | 34.8 | 116 | 27 | 33.3 |
| | 1/2 | 65 | 37.6 | 47 | 87 | 35.9 | 45.4 | 68 | 35.8 | 44.8 | 121 | 33.2 | 42 | 58 | 35.7 | 44 | 98 | 33.6 | 42 | 60 | 36.3 | 44.8 | 101 | 32.8 | 41 | ... | .... | .... | ... | .... | .... |
| | 3/4 | ... | .... | .... | ... | .... | .... | 59 | 42.2 | 52.8 | 106 | 39.5 | 50 | ... | .... | .... | ... | .... | .... | ... | .... | .... | ... | .... | .... | ... | .... | .... | ... | .... | .... |
| 80 | 1/4 | 123 | 31.4 | 39.2 | 167 | 30 | 38 | 128 | 30.2 | 37.7 | 231 | 28.5 | 36.1 | 112 | 30.2 | 37.3 | 189 | 28.1 | 35.1 | 114 | 29.7 | 36.7 | 193 | 27.8 | 34.8 | 93 | 30 | 36.6 | 150 | 28.8 | 34.9 |
| | 1/2 | 81 | 39 | 48.8 | 110 | 37 | 46.8 | 85 | 37.2 | 46.5 | 153 | 34.3 | 43.4 | 74 | 37.1 | 45.8 | 129 | 34.4 | 43 | 75 | 36.3 | 44.8 | 128 | 33.9 | 42.4 | 61 | 36.6 | 44.6 | 99 | 34.6 | 42.7 |
| | 3/4 | 71 | 45.4 | 56.8 | 95 | 43.7 | 52.8 | 74 | 43.7 | 54.6 | 132 | 40.8 | 51.6 | 65 | 43.4 | 53.4 | 108 | 41 | 51.3 | 66 | 42.6 | 52.6 | 111 | 40.4 | 50.5 | 53 | 42.9 | 52.3 | 87 | 40.9 | 50.5 |
| 60 | 1/4 | 173 | 33.3 | 41.8 | 235 | 31.6 | 40 | ... | .... | .... | ... | .... | .... | 158 | 32.1 | 39.6 | 266 | 29.8 | 37.3 | ... | .... | .... | ... | .... | .... | 131 | 32 | 39.1 | 212 | 30.1 | 37.2 |
| | 1/2 | 111 | 40.9 | 51.2 | 149 | 38.9 | 49 | 116 | 39.4 | 49.2 | 207 | 35.8 | 45.3 | 100 | 39.3 | 48.5 | 169 | 36.3 | 45.4 | 102 | 38.5 | 47.1 | 173 | 35.7 | 44.7 | 83 | 39.2 | 47.8 | 135 | 36.6 | 45.2 |
| | 3/4 | 101 | 46.9 | 59.4 | 128 | 45.5 | 57.6 | 100 | 45.9 | 57.4 | 179 | 42.6 | 53.9 | 86 | 45.9 | 56.7 | 146 | 42.9 | 53.6 | 88 | 45.1 | 55.7 | 149 | 42.2 | 52.8 | 72 | 45.4 | 55.4 | 116 | 43.2 | 63.3 |
| Net H. P. | | 30 | | | | | | 40 | | | | | | 50 | | | | | | 60 | | | | | | 70 | | | | | |
| Diameter × stroke, in in. | | 10 × 24 | | | 10 × 15 | | | 11 × 30 | | | 11 × 18 | | | 12 × 30 | | | 12 × 18 | | | 13 × 36 | | | 13 × 21 | | | 14 × 36 | | | 14 × 21 | | |
| 100 | 1/4 | 70 | 28.2 | 34.4 | 113 | 26.8 | 33.1 | 61 | 28.4 | 34.2 | 103 | 26.7 | 32.6 | 64 | 27.9 | 33.6 | 108 | 26.3 | 32.1 | 54 | 28 | 33.3 | 93 | 26.6 | 32.1 | 54 | 27.7 | 33 | 94 | 26.3 | 31.7 |
| 80 | 1/4 | 90 | 29.8 | 36.3 | 146 | 28.1 | 34.7 | 79 | 29.9 | 36 | 133 | 28.1 | 34.3 | 83 | 29.4 | 35.4 | 139 | 27.7 | 33.8 | 69 | 29.6 | 35.2 | 121 | 27.9 | 33.6 | 70 | 29.3 | 34.9 | 121 | 27.7 | 33.3 |
| | 1/2 | 60 | 36.2 | 44.1 | 97 | 35.4 | 43.7 | ... | .... | .... | .. | .... | .... | 54 | 35.8 | 43.1 | 92 | 33.9 | 41.3 | ... | .... | .... | ... | .... | .... | ... | .... | .... | ... | .... | .... |
| 60 | 1/4 | ... | .... | .... | ... | .... | .... | 111 | 32.2 | 38.8 | 187 | 29.9 | 36.5 | 116 | 31.6 | 38.1 | 191 | 29.7 | 36.2 | ... | .... | .... | ... | .... | .... | ... | .... | .... | ... | .... | .... |
| | 1/2 | 81 | 38.8 | 47.3 | 131 | 36.4 | 44.9 | 70 | 39 | 47 | 119 | 36.2 | 44.2 | 74 | 38.3 | 46.3 | 125 | 35.7 | 43.5 | 62 | 38.6 | 46 | 108 | 36.2 | 43.6 | 63 | 38 | 45.2 | 108 | 36 | 43.4 |
| | 3/4 | 70 | 45 | 54.9 | 114 | 42.9 | 53 | 61 | 35.4 | 54.7 | 102 | 42.8 | 52.2 | 64 | 44.5 | 53.6 | 108 | 42.2 | 51.5 | 54 | 44.8 | 53.3 | 93 | 42.7 | 51.5 | 54 | 44.4 | 55.9 | 93 | 42.4 | 51.1 |
| Net H. P. | | 80 | | | | | | 90 | | | | | | 100 | | | | | | 125 | | | | | | 150 | | | | | |
| Diameter × stroke, in in. | | 15 × 36 | | | 15 × 24 | | | 16 × 42 | | | 16 × 24 | | | 17 × 42 | | | 17 × 30 | | | 19 × 48 | | | 19 × 30 | | | 21 × 48 | | | 21 × 30 | | |
| 100 | 1/4 | 54 | 27.5 | 32.7 | 82 | 26.5 | 31.9 | 45 | 27.7 | 32.6 | 80 | 26.4 | 31.4 | 45 | 27.5 | 32.4 | 61 | 26.9 | 32 | ... | .... | .... | ... | .... | .... | 40 | 27.1 | 31.4 | 61 | 26.4 | 31.1 |
| 80 | 1/4 | 70 | 29.1 | 34.6 | 106 | 27.9 | 33.6 | 58 | 29.4 | 34.6 | 103 | 27.9 | 33.2 | 57 | 29.3 | 34.9 | 79 | 28.5 | 33.9 | 50 | 29.4 | 34.2 | 80 | 28.1 | 33 | 52 | 28.9 | 33.6 | 79 | 28 | 32.9 |
| 60 | 1/4 | ... | .... | .... | ... | .... | .... | 82 | 31.9 | 37.5 | 145 | 30 | 35.7 | 81 | 31.8 | 37.4 | 112 | 30.7 | 36.6 | 60 | 31.9 | 37.1 | 113 | 30.4 | 35.8 | 73 | 31.4 | 36.5 | 112 | 30.2 | 35.5 |
| | 1/2 | 62 | 38 | 45.2 | 95 | 36.2 | 43.6 | 52 | 38.4 | 45.2 | 93 | 36.1 | 43 | 51 | 38.2 | 44.9 | 71 | 37.1 | 44.2 | 45 | 38.3 | 44.5 | 72 | 36.5 | 43 | 46 | 37.8 | 44 | 71 | 36.3 | 42.7 |
| | 3/4 | ... | .... | .... | ... | .... | .... | 45 | 44.7 | 52.6 | 80 | 42.5 | 50.6 | 44 | 44.4 | 52.2 | 61 | 43.4 | 51.4 | ... | .... | .... | ... | .... | .... | 40 | 44 | 51.8 | 61 | 42.8 | 50.4 |

1444.

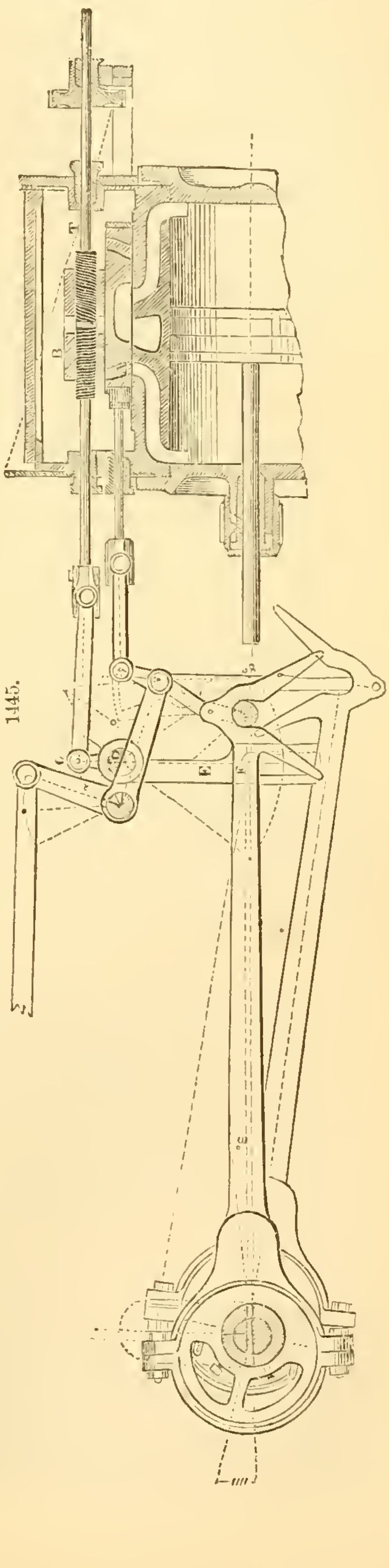



posed. The ordinary valve is worked in the usual manner; but the travel of the supplementary valve may be lengthened or shortened, so as to cut off the steam at any part of the stroke. *A* is the common valve, and *F* the valve-chest. *B* is the supplementary valve, which is a solid block with two perforations, which, when opposite the ports in the cover *F*, admit steam from the supplementary valve-chest *K*. The starting-handle is connected with the shaft *g*, upon which a lever is fixed, and so connected by links with the extremities of the eccentric-rods *D* and *d*, that when one eccentric-gab is in gear with the pin *e'* upon the valve-lever, the other shall be disengaged. In the figure the engine is in gear for going ahead, and the reversing eccentric-rod *D* is disengaged from the ordinary valve, and in gear with the supplementary valve, by means of a second gab *f*, which receives a pin upon the expansion-valve lever *G*. In this lever there is a long slot, in which a pin *G*, fixed on the valve-link *H*, may be moved to a greater or less distance from the centre of the expansion-valve shaft, by means of a handle *t*; and the effective length of the valve-lever being thus varied, the travel of the valve receives a corresponding variation. The expansion-valve thus receives the reversing motion while the slide-valve is receiving the forward motion.

Fig. 1445 represents the variable expansion gear of Mayer. It consists of an ordinary valve, with the addition of perforations through the top and bottom faces, each of which is covered by a supplementary valve upon the back of the first, consisting of two solid blocks, into which a valve-rod is screwed, having a right-handed screw where it penetrates the one block, and a left-handed screw where it penetrates the other; so that the blocks will be set closer or farther apart, according to the direction in which the rod is turned. The ordinary valve receives its motion in the usual way, and the expansion-valve is moved by means of a pin attached to the piston-rod, which works in a slotted lever, to which the expansion-valve rod is attached. The motion of the two valves is, therefore, at right angles, and the expansion-valve is about one-fourth of a revolution in advance of the steam-valve. In Fig. 1445, *A* is the steam-valve; *B*, the expansion-valve; *T*, the valve-rod, with right- and left-handed screw; *G*, a wheel attached to the valve-rod, over which a pitch-chain passes, by means of which the valve-rod is turned, and the blocks are altered so as to give the requisite amount of expansion; *D*, the valve-shaft, and *C E*, the valve-lever; *F*, the pin attached to the piston-rod. In all cases in which the motion of the expansion-valve is the same as that of the piston, the slide-valve must be provided with lap.

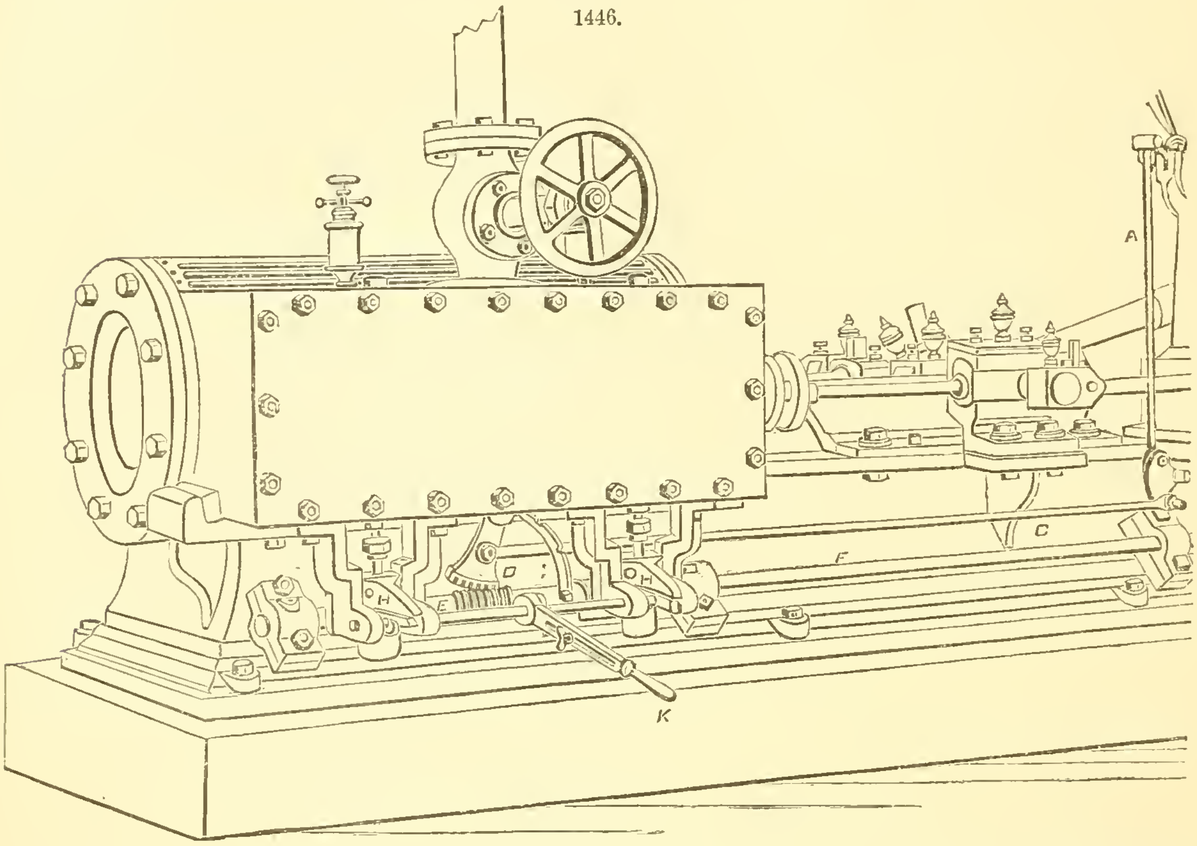
The general arrangement of Watt's and Phelps's variable cut-off is represented in Figs. 1446 to 1448. The following description is from the *Scientific American* for Jan. 21, 1871: "The controlling power of the governor is transmitted through the connecting-rod *A*, Fig. 1446, the sector *B*, the connecting-rod *C*, and the toothed sector *D*, to a cylindrical rack turned on the sleeve *E*. The sleeve *E* is feathered to the shaft *F*, and slides longitudinally when acted upon by the parts *A*, *B*, *C*, and *D*, while turning with the shaft *F*, the rotation of the latter being accomplished through a system of gearing from the crank-shaft. The sleeve *E* also carries two cams, shown in section in Fig. 1448, at *G*, which, turning under the toes of tappet-arms *H*, Figs. 1446 and 1448, attached to the vertical stems *I*, Fig. 1448, of the cut-off valves *J*, Figs. 1447 and 1448, raise the valves and let them fall abruptly at the proper point of cut-off to which they are adjusted. The cut-off valves are of the 'grid' variety, and slide on the backs of the principal

1445.



valves, which latter are actuated in the usual way from an eccentric on the crank-shaft. The sliding of the sleeve $E$ on the shaft $F$ causes the cams to let the cut-off valves fall earlier or later in the stroke, according as varying velocity affects the governor. If the belt breaks, or any other derangement of the governor occurs, the travel of the sleeve, being a little more than the length of the cam, allows the toes of the tappet-arms to drop off the cam on to the shaft, closing the cut-off valve ports and instantly stopping the engine. In starting the engine, a lever and cam, $K$, Figs. 1446 and 1448, is used to raise the cut-off valve and open the port. The motion of the engine then, operating on

1446.

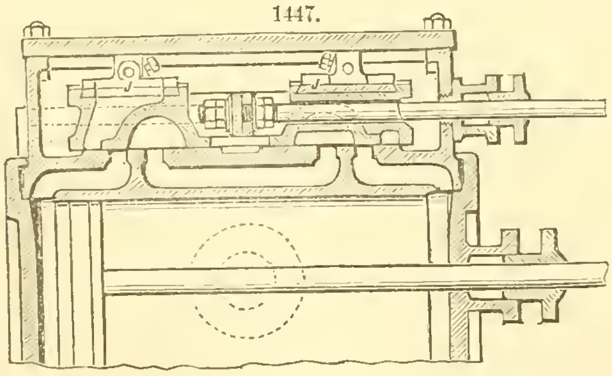



the governor, draws the sleeve along so as to bring the cams under the tappets, and thenceforward the gear works automatically. It will be seen that this gear can be made to cut off from zero to any part of the stroke desired."

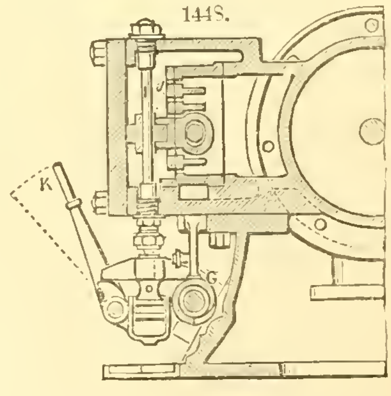
The principle of Sickels's cut-off is to detach the main valve from the stem at any desired point, and close it by springs or weights. As originally applied to puppet-valves, the valve was detached from the stem as it was rising, and allowed to seat by its own weight, being cushioned in its descent by a dash-pot containing air or water. In later forms of the cut-off, the valve was detached from the stem by a sliding or vibrating arm having motion coincident with that of the piston, so that the cut-off was effected at any desired point of the stroke. Many other cut-offs have been constructed on this principle, prominent among which is the Corliss cut-off.

The original form of the Corliss engine, on its introduction, is shown in the full-page illustration.

1447.



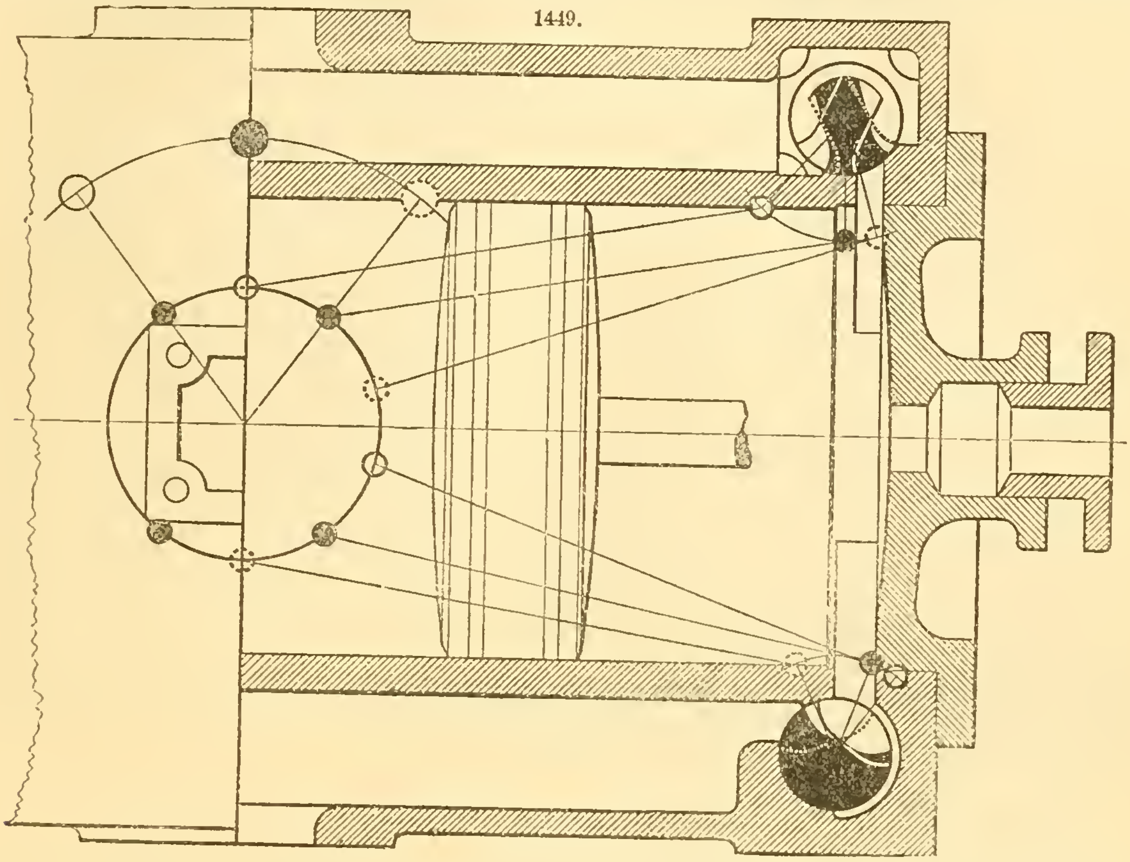
1448.




Its chief peculiarities lie in the method of working the valves, and in controlling the valve motion by the governor, so as to regulate the motion of the engine and use the steam to the best advantage under all conditions. The valves employed are rotary sliding valves. Their motion is similar to that of the common plug-cock or faucet, but the form adopted is such that they fill a portion only of the cylindrical cavities in which they are mounted. The connection of each valve to its spindle or stem is such that it is free to adapt itself to all conditions. It works freely and yet remains tight, precisely like an ordinary slide-valve. There are two steam-valves and two exhaust-valves, all worked

independently, yet by simple mechanism. The exhaust-valves are held open during the whole stroke of the piston, but the steam-valves are opened at the proper time and allowed to shut automatically at some point in the early part of the stroke. The precise point at which this shutting of the steam-

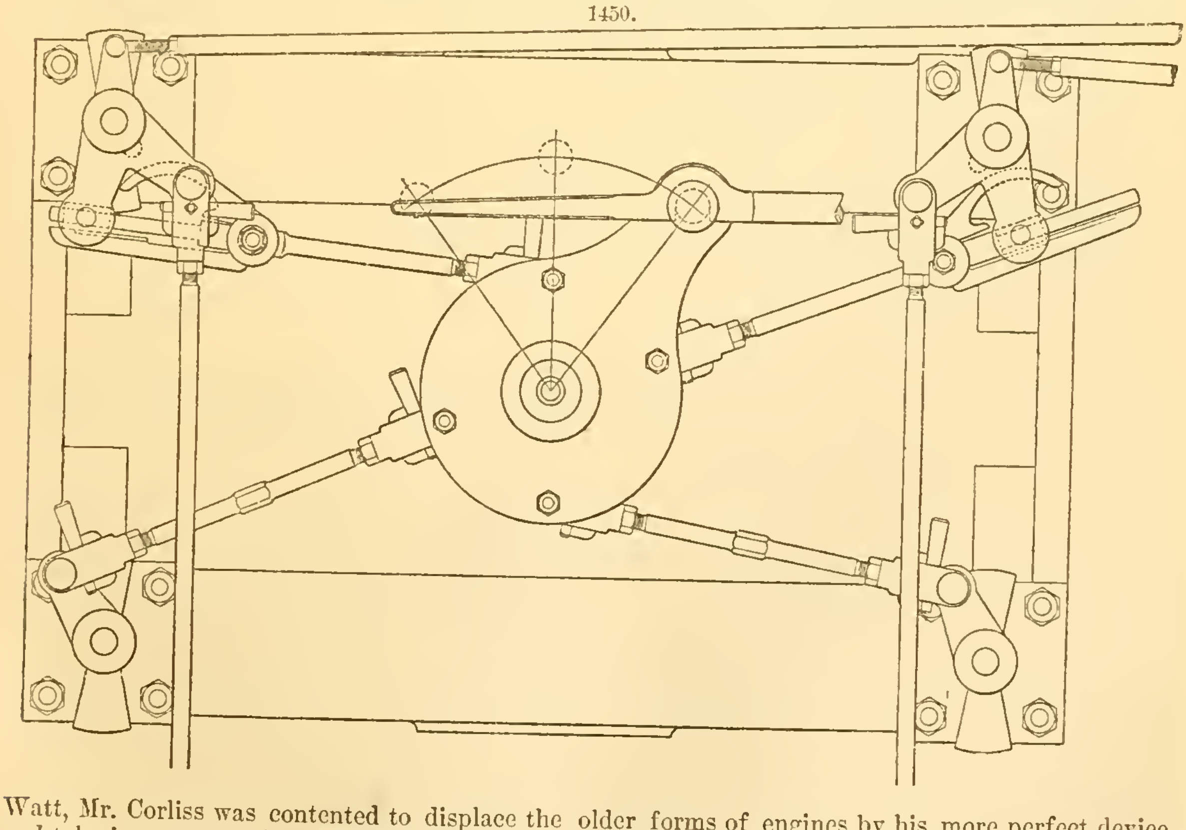
1449.



valve occurs, and consequently the volume of steam admitted into the cylinder in any given stroke, depends on the position of the governor-balls, and the speed of the engine is regulated by the variations in the quantity of steam thus admitted.

The invention of the Corliss engine marks an era in steam-engine construction, and the history of its introduction bears a striking analogy to that of the pumping engine invented by Watt. Like

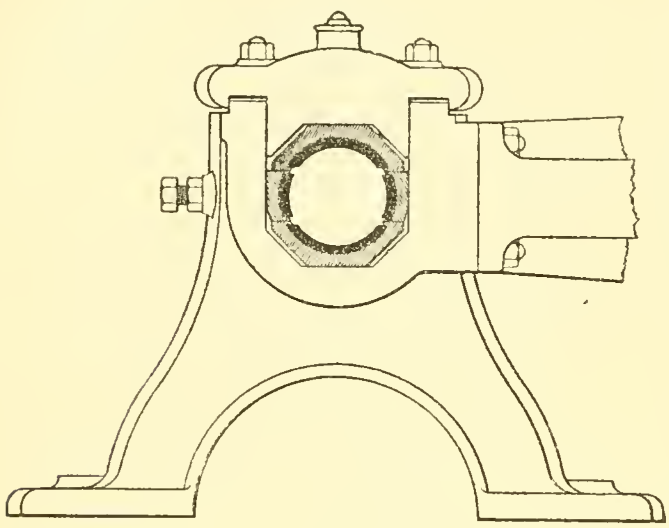
1450.



Watt, Mr. Corliss was contented to displace the older forms of engines by his more perfect device, and take in payment the value of a portion of the coal saved; and like Watt, he soon found that proprietors of mills were unwilling to render him true accounts of the saving effected. Now that

the patent has expired, the Corliss engine, or some modification, has been largely adopted as the standard design by engine-builders in this country; and it has displaced almost all other styles abroad. No device for regulating the distribution of the steam in stationary engines has been invented that successfully supersedes the Corliss wrist-motion; and this attachment, together with improved construction and increased piston-speed, has increased the efficiency of the stationary engine quite as much as 100 per cent.

1451.



The action of the Corliss wrist-motion is plainly illustrated in Fig. 1449, which shows the valves at one end of the cylinder, in the two extreme and middle positions. The sketch will repay study, showing in an admirable manner the effect of the peculiar mode of connection. The example is from the Corliss engine as built by Watts, Campbell & Co.; and Fig. 1450 is from a working drawing of one of their cylinders, showing valve-motion, and device for tripping the steam-valves by the rod connected to the governor. The valve, when tripped, is closed either by weights or springs, dash-pots being ordinarily used in connection with weights. Fig. 1451 represents the main bearing used by Watts, Campbell & Co. on their engines; the top and bottom brasses not being fitted, but having a little play allowed, any adjustment required being made on the centre brasses, as shown.

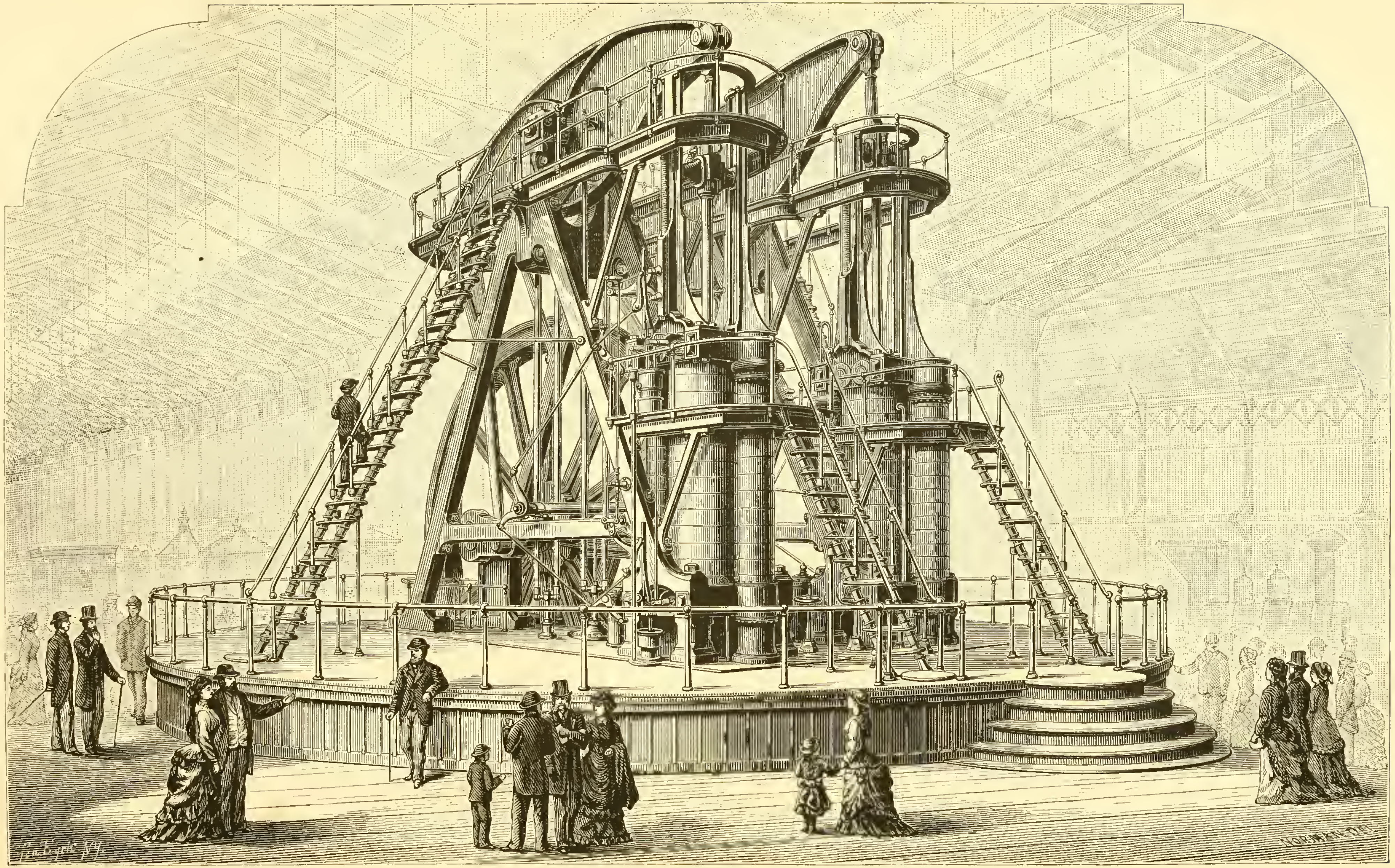
One of the finest examples of the Corliss engine ever constructed was the pair of engines built by Mr. Corliss for use in Machinery Hall at the Centennial Exhibition. These engines are illustrated in a full-page engraving, and the principal dimensions are appended:

| | |
|---|---|
| Diameter of cylinder, inches | 40 |
| Stroke of piston, feet | 10 |
| Diameter of air-pump, inches | 36 |
| Stroke " " | 24 |
| Diameter of piston-rod (steel), inches | 6.25 |
| Length of beam between centres, feet | 25 |
| Depth of beam at centres, feet | 9 |
| Weight of beam, lbs | 22,000 |
| Length of crank-shaft, feet | 12 |
| Diameter of " inches | 19 |
| " " " bearings, inches | 18 |
| Length " " " | 27 |
| Diameter of fly-wheel at pitch-line, feet | 29.7 |
| Pitch of teeth, inches | 5.183 |
| Face of fly-wheel, inches | 24 |
| Weight of fly-wheel, lbs | 112,000 |
| Number of teeth in fly-wheel | 216 |
| Diameter of pinion at pitch-line, feet | 9.9 |
| Weight of pinion, lbs | 17,000 |
| Revolutions of engines per minute | 36 |
| Total revolutions during the Exhibition | 2,355,300 |

These engines were let by Mr. Corliss, during the Exhibition, for $77,000, the Board of Finance building the boiler-house, making the necessary excavations, and furnishing the fuel—thus bringing the whole cost up to $142,374. According to a statement made by Mr. Corliss, his expenditures were in excess of his receipts by $40,788.10.

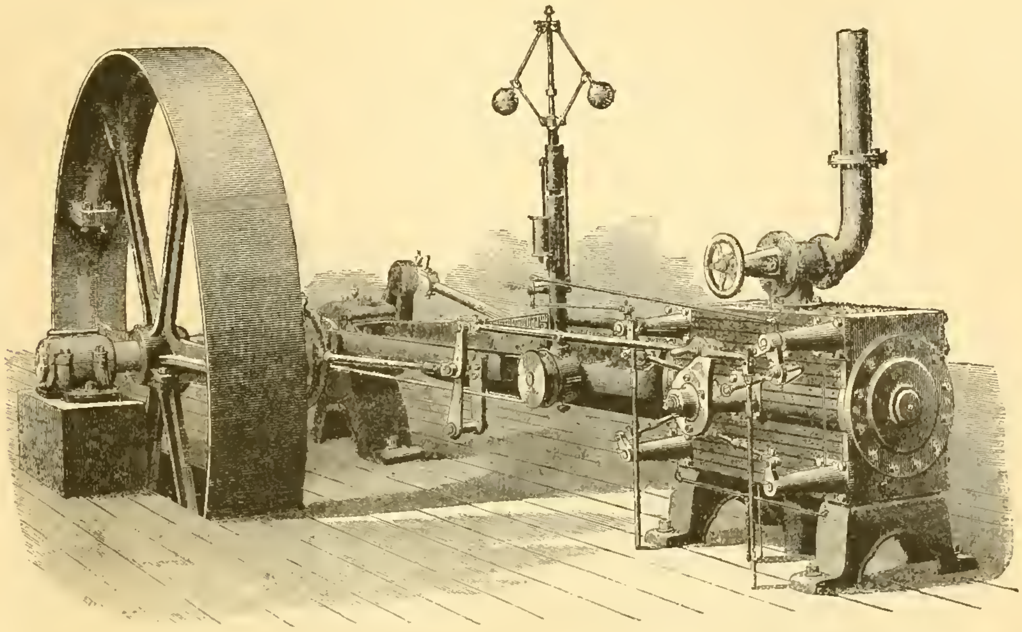
*The Harris-Corliss Engine.*—Fig. 1452 represents a modified form of the Corliss engine largely used in the United States. Fig. 1453 is a longitudinal section of the cylinder, steam-chest, and exhaust-passage, with cross-sections of the valves. At $A$ is shown one steam-port open, and at $B$ the other steam-port closed; $C$ is one exhaust open full area of port, and $D$ the other exhaust closed. It will be noticed in Fig. 1453 that the piston has traveled a very small part of the stroke while the steam- and exhaust-valves $A$ and $C$ have been opening the full area of their ports. Fig. 1454 shows the method of packing the valve-stems so as to obviate the use of stuffing-boxes and to cause the thrust-collar to bear directly against the bonnet $E$. $D$ is the valve-stem, on which is shrunk the collar $F$, which fits in a recess $a$ of the bonnet. The opposing faces are finely scraped so that they approximate very closely, and are packed by the steam itself acting outward on an area equal to the section of the valve-stem $D$. In the hollow space in the bonnet all drip enters, and is carried off by the pipes $G$, which extend from bonnet to bonnet. (See "Economy Trials of an Automatic Engine," by John W. Hill, M. E., in *Van Nostrand's Engineering Magazine*, December, 1877.)

*The Wheelock Engine.*—An elevation of this engine, and a modification of the Corliss valve-gear patented by Jerome Wheelock, are shown in Figs. 1455 and 1456. In this arrangement there

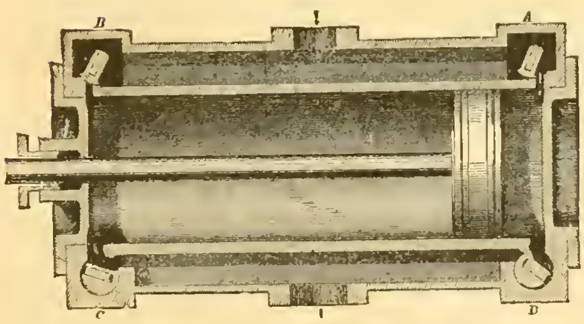


THE CORLISS BEAM STEAM-ENGINE.

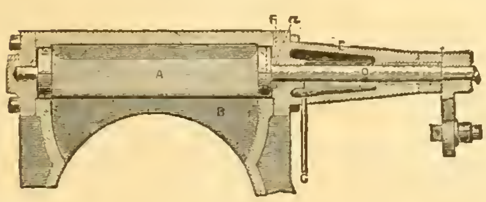
1452.



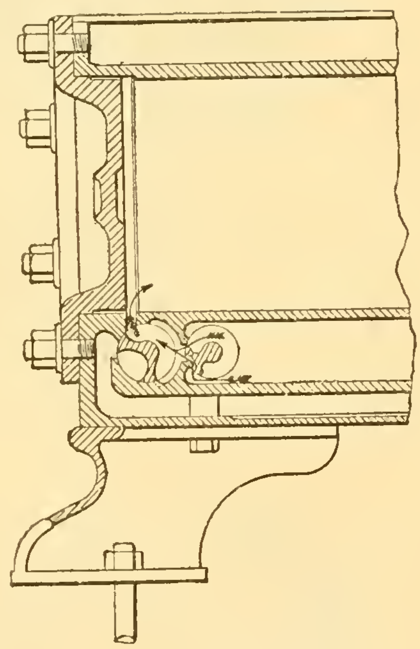
1453.



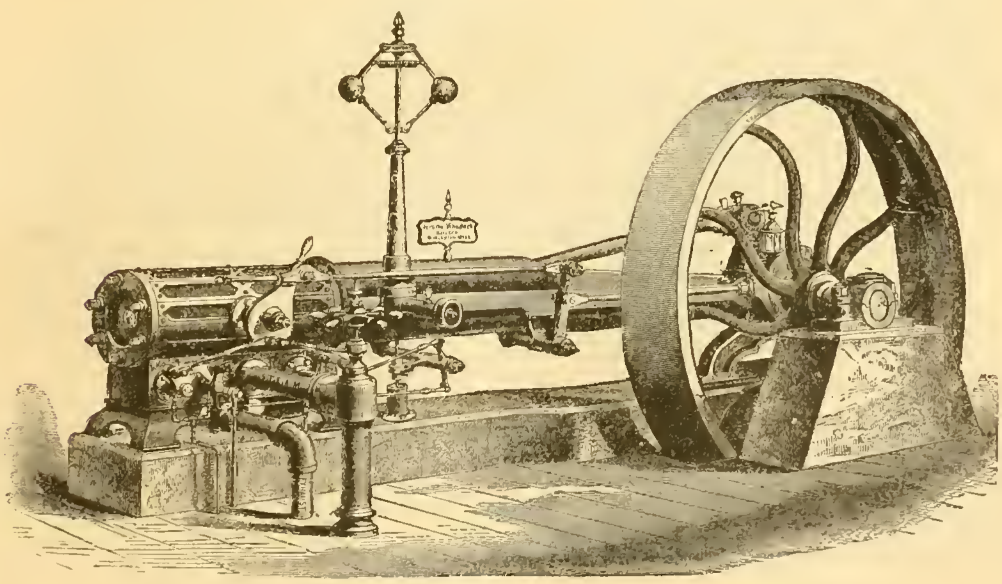
1454.



1456.



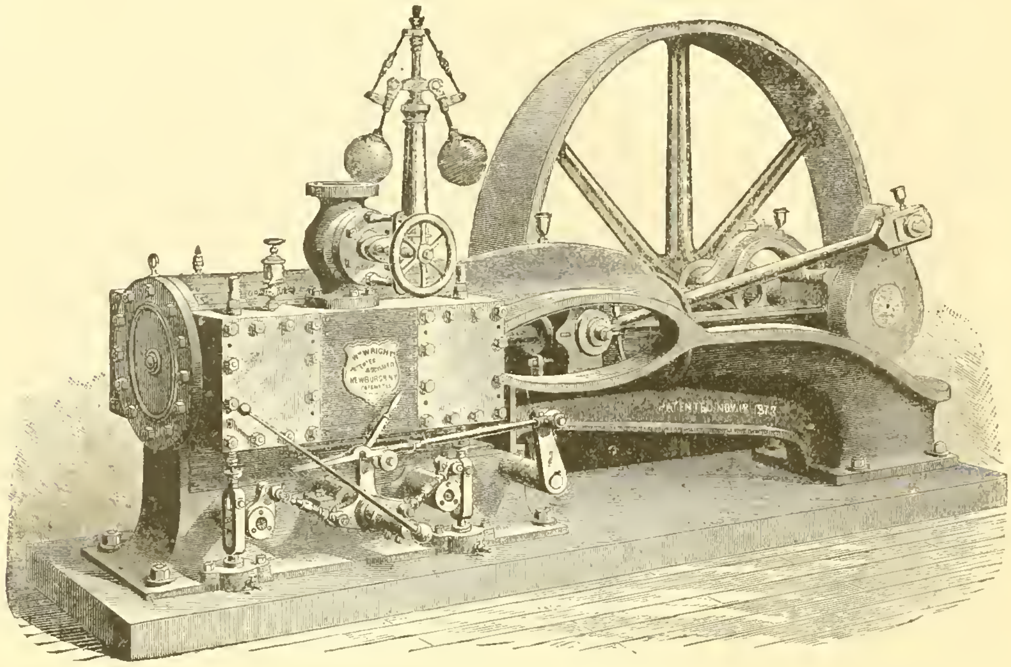
1455.



is only one port in each end of the cylinder, an independent cut-off valve regulating the admission of steam. The cut-off valve is of such a form as to allow a double admission and cut-off, which is an arrangement very favorable to the distribution for a given port area. The valves rotate on hardened steel bushings, which are adjustable endwise, and no stuffing-boxes are used.

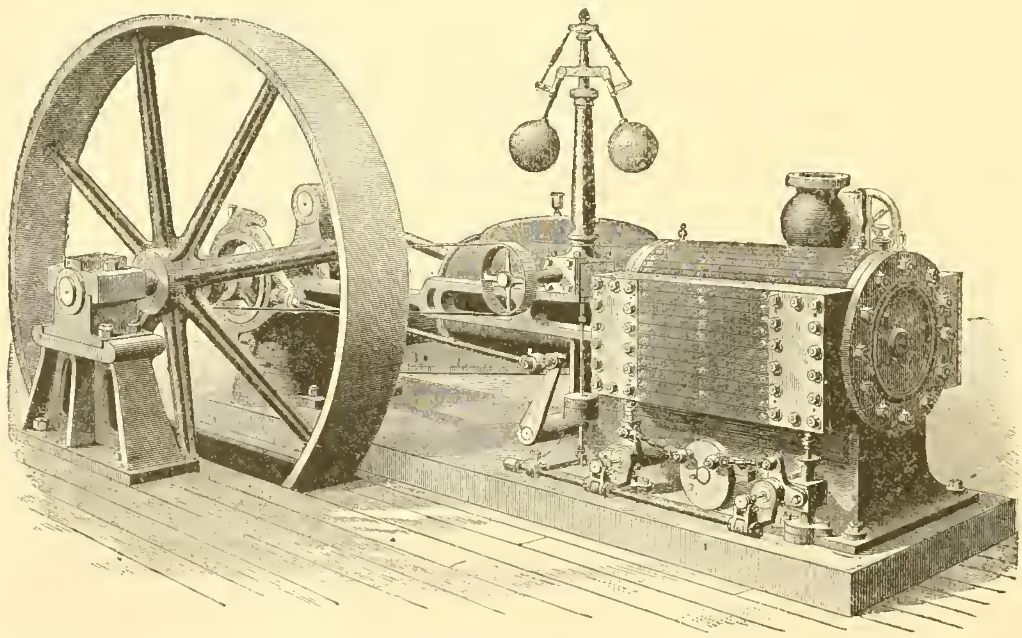
*The Wright Automatic Cut-off Engine* is the invention of Mr. William Wright of Newburgh, N. Y. Fig. 1457 shows the steam side with the cut-off valve gear, and Fig. 1458 the exhaust side. There

1457.



are four gridiron slide-valves, which work vertically in chests cast with the cylinder, two upon one side of the cylinder being for induction, or cut-off, and two upon the opposite side being for eduction, or exhaust steam. All valve-motion is derived from a single eccentric, which operates levers, so arranged as to give a quick movement to valves when opening, and also a very slow movement when valves are lapped. The location of all these valve-faces close to the bore of the cylinder insures the least possible amount of clearances. The steam valve-stems are fastened in yokes, which have at their lower ends plungers fitted in dash-pots, the same acting as guides; the yokes are operated by steel slides fitted through the end of hollow rocker-arms, and which act upon the swinging toes held in the yokes, the said slides having a diagonal slot in which works a feather, this feath-

1458.

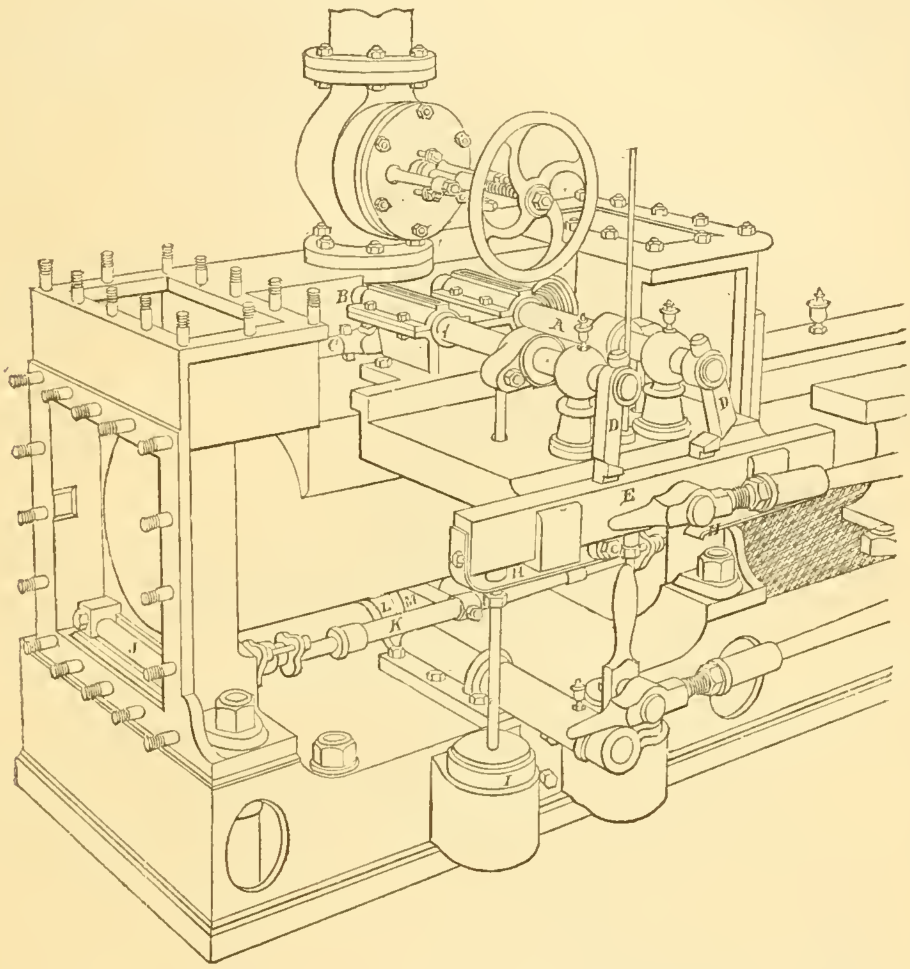


er being made on a rod which has a longitudinal movement through the hollow rocker-arm, and to which the governor is connected. By this longitudinal motion, and through the diagonal feather and slot, the slide is automatically set, to engage more or less with the swinging toes, and which gives the valve its proper lift, and liberates upon the chord of the arc. The governor itself stands on a bracket or shelf, cast on the slide part of the bed-plate, and the governor-rod is connected to a lever, which is fastened to the governor-shaft. This same shaft carries two forked arms which take hold

of the small rods running through the hollow rocker-shafts. The rods are enlarged at their other ends, where they carry the adjustable slides mentioned before. The advantages in this arrangement of valves and valve-gearing are easy accessibility to each valve, by the simple removal of a bonnet, and that the whole of the valve-gear and governor connections is outside of the steam-chests, where any derangement can be at once seen and rectified.

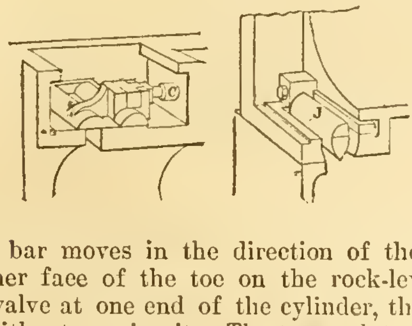
*The Greene Engine*, manufactured by the Providence Steam-Engine Company, of Providence, R. I.,

1459.

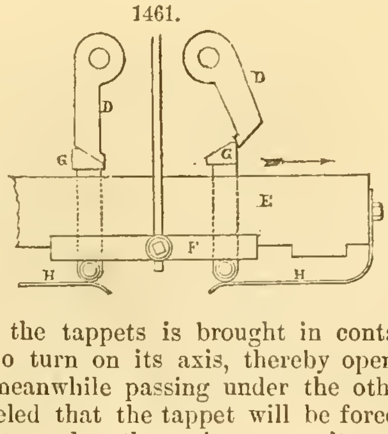



is represented in Figs. 1459, 1460, and 1461. There are four flat slide-valves, one (as shown on the left of Fig. 1460) at each end on the top to admit the steam, and one (as shown on the right of Fig. 1460) to let out the exhaust. The working of the valve-gear is as follows: The induction-valves are connected with the rock-lever shafts $A$, Fig. 1459, by arms $B$ working in slots in the valve-stems $C$. Below the rock-levers $D$ $D$ is a sliding bar $E$, receiving a reciprocating motion from an eccentric on the main shaft. Behind the sliding bar is a gauge-bar $F$, Fig. 1461, connected with the governor, which bar receives an up-and-down motion from a corresponding movement of the governor-balls. The adjustable tappets $G$ $G$, Fig. 1461, in the sliding bar, are kept up in contact with the gauge-bar $F$, and are made to move up and down in unison with it by the springs $H$ $H$. As the

1460.



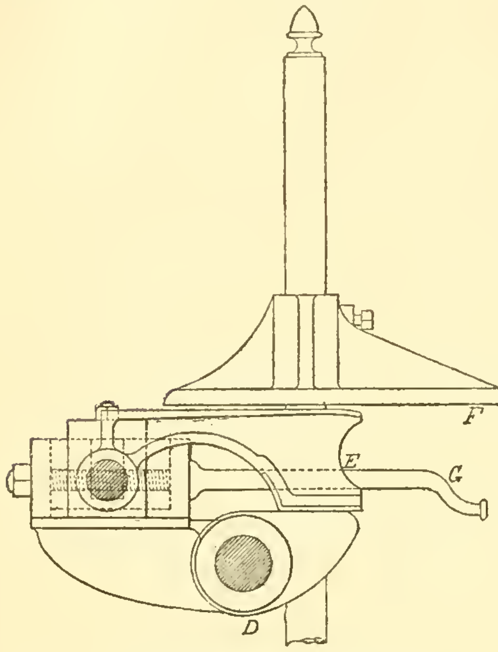

1461.




sliding bar moves in the direction of the arrow, one of the tappets is brought in contact with the inner face of the toe on the rock-lever, causing it to turn on its axis, thereby opening the steam-valve at one end of the cylinder, the other tappet meanwhile passing under the other rock-lever without moving it. The toe and tappet are so beveled that the tappet will be forced down against the action of this spring until it has passed by the toe, when the spring causes it to fly up to its original position, ready to open the induction-valve at the opposite end. As a result of this motion, the two tappets always open the steam-valves at the same period; but, the tappet moving in a straight line while the toe describes the arc of a circle, the tappet will pass by, liberating the toe,

which is brought back to its original position by a weight *I*, Fig. 1459, the steam-pressure on the valve-stem thus closing the valve and cutting off the steam. This liberation will take place sooner or later, according to the elevation of the tappets; that is, the lower the tappets are the sooner the toes will be liberated, and *vice versa;* and so, by simply elevating or depressing the gauge-bar *F*, Fig. 1461, the period of closing the valves can be changed while the period of opening them remains the same. The adjustment of the gauge-bar is effected by the governor, and the steam is cut off sooner or later according to the amount of load. The exhaust-valves *J*, Fig. 1459, which lie in the bottom of the cylinder, are connected at their outer ends by parallel rods *K*, which are tied together by a cross-bar on the inside. The exhaust rock-shaft arm *L* is a jaw, as shown in Fig. 1459, just under the cylinder. One side of this jaw comes in contact with a lug *M* on the cross-bar, and moves both the exhaust-valves simultaneously, opening one and closing the other. While the exhaust-eccentric is taking up the lost motion between the sides of the jaw, the exhaust-valves remain at rest. The other side of the jaw coming in contact with the cross-bar, the exhaust-valves receive a reverse motion. The lug on the cross-bar is so shaped that it receives no blow from the jaw *L*, but takes a gradually accelerated motion.

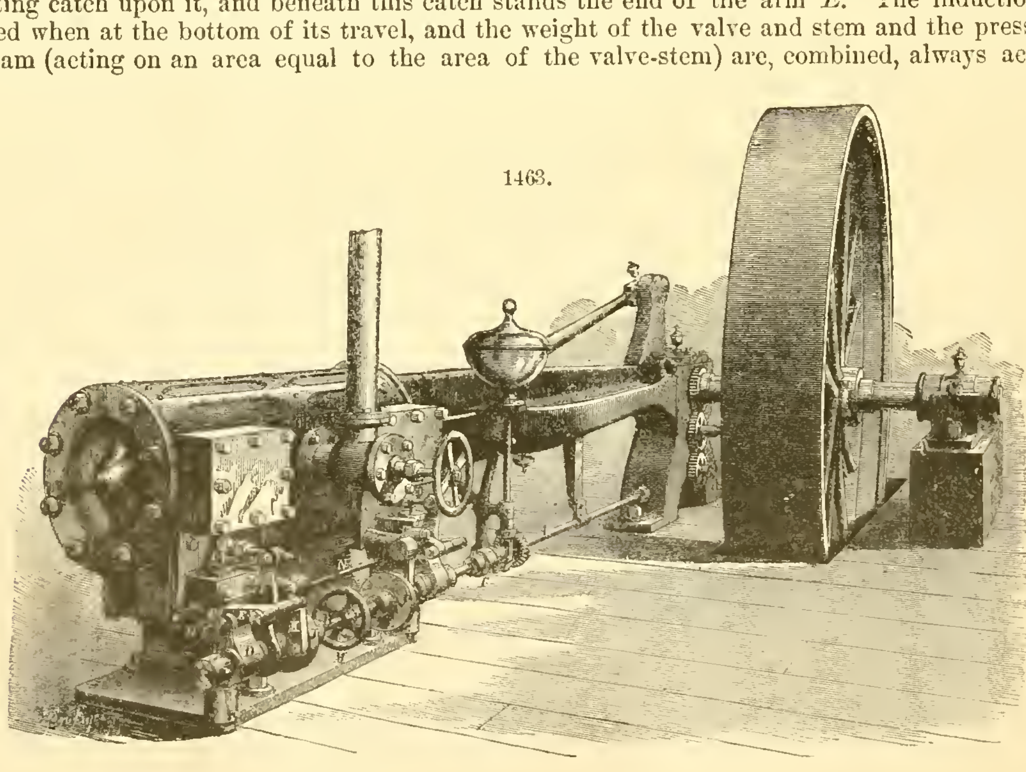
1462.



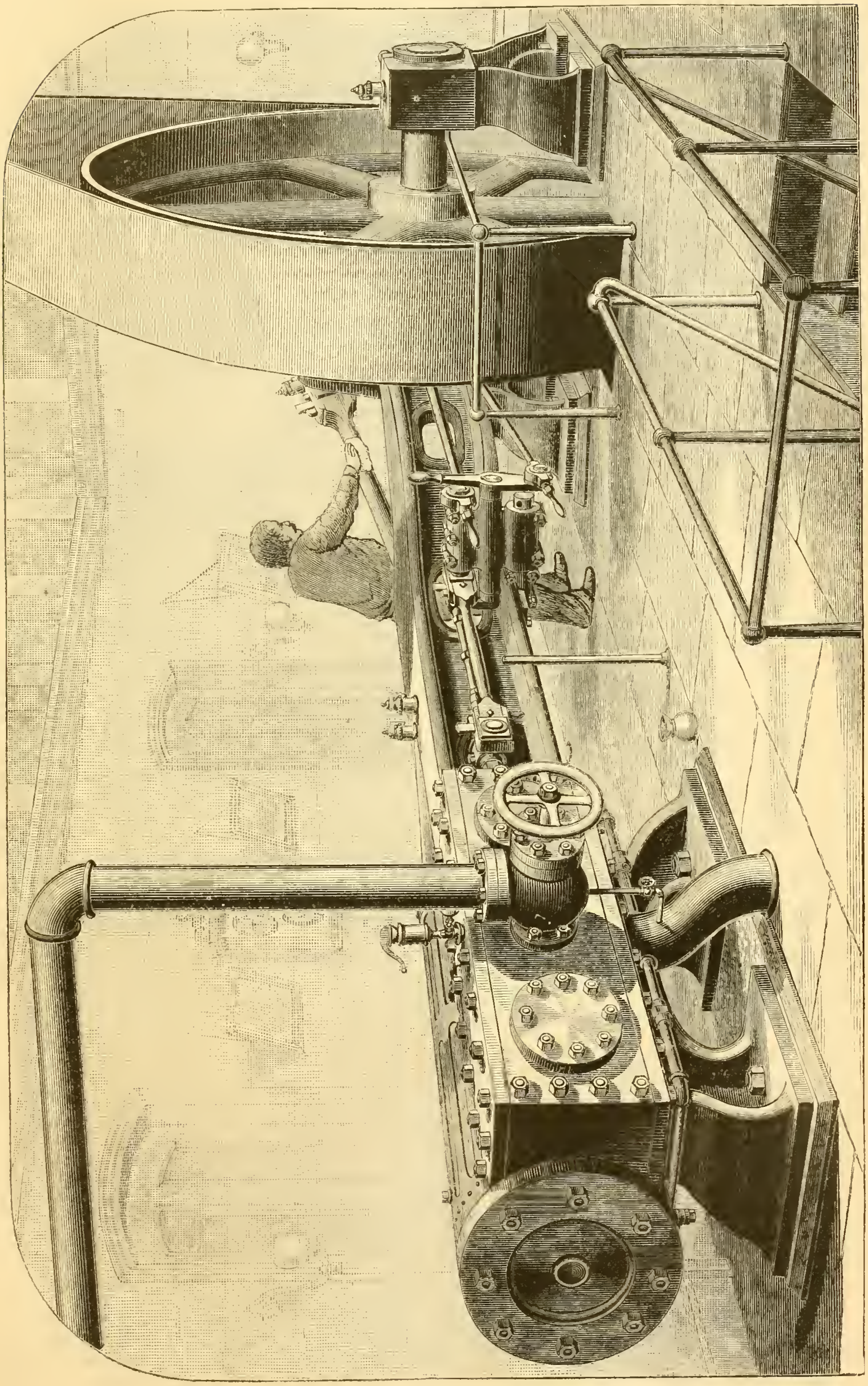

*Winter's Cut-off*, Fig. 1462.—In this the shaft *D* receives a rotary motion from the eccentric-rod, the latter being pivoted to a lever between its points of attachment to the eccentric and shaft *D*. A cam on this revolving shaft acts on the lifter *F* to open the valve, through the piece *E;* the duration of contact, or the point of cut-off, being regulated by the position of the piece *E*, which can be adjusted as shown.

*The Brown Engine*, Fig. 1463.—The cut-off mechanism in this engine is the invention of Mr. C. H. Brown of Fitchburg, Mass. Its arrangement is as follows: The cut gear-wheels shown impart a rotary motion to the shaft *A*, which operates the governor and communicates rotary motion to the valve-shaft *B*. Between these two shafts is a friction device *C*, which is so constructed as to permit the shaft *B* to be operated by hand independently of the shaft *A*. Upon the shaft *B* are the eccentrics, the ends of the straps of which connect with the horizontal lever *E;* and the latter extends into the square slot in the slide-spindle guide to the catch of the tongue. As the shaft *B* revolves, the lever *E* reciprocates vertically in the said square slot. The valve-stem is attached to the guide *F*, and in the slot shown in the latter is pivoted a tongue *G*. The upper end of this tongue has a projecting catch upon it, and beneath this catch stands the end of the arm *E*. The induction-valve is closed when at the bottom of its travel, and the weight of the valve and stem and the pressure of the steam (acting on an area equal to the area of the valve-stem) are, combined, always acting to

1463.



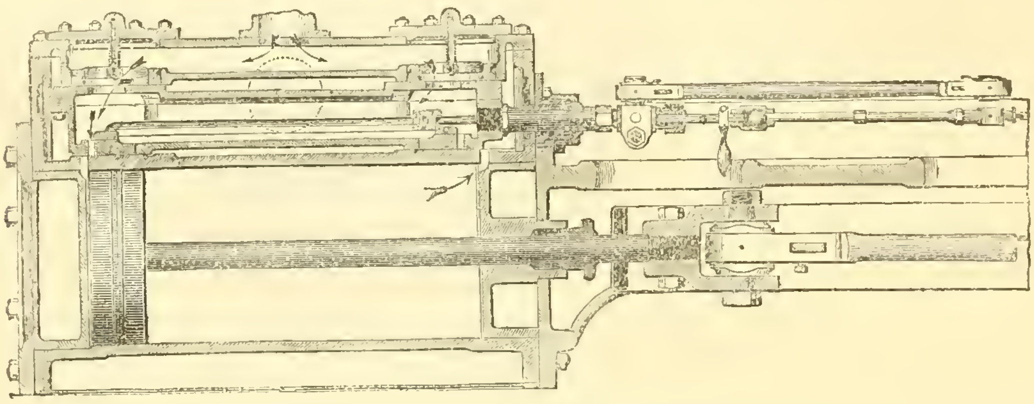
keep the valve at the bottom of its travel, that is, in its normal position; and there it remains until lifted for the admission of steam. The manner of effecting this admission is as follows: The end of the arm *E*, acting against the catch on the upper end of the tongue in the slot, lifts the valve and



1464.

holds it open so long as the tongue is not tripped. The instant, however, that the latter action takes place, the valve, from its weight and the action of the steam upon the area above mentioned, closes, the movement being cushioned after the valve is completely closed by means of the small dash-pot shown beneath. By regulating the eccentrics, the valve may be given any desired amount of lead, and the duration of the period of admission may be varied by tripping the tongue before referred to; and this is accomplished by the engine governor in the following manner: The governor communicates with the rod *N*. Upon this rod, and immediately behind the induction-valve spindle-guide *F*,

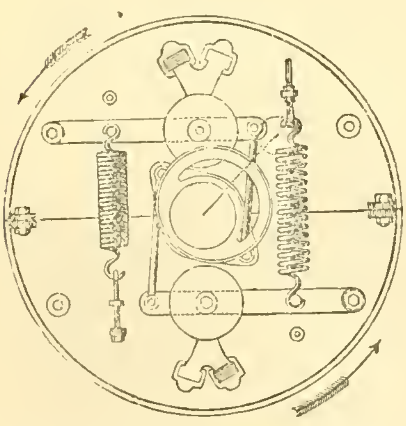
1465.

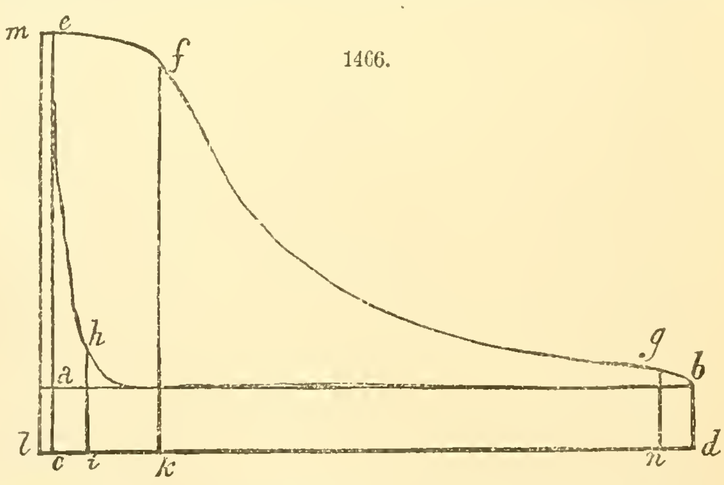


is an arm standing vertically, and carrying a pin *H* standing horizontally. The tongue, which at one end acts as a catch to the eccentric arm at the other end, protrudes from the back of the slide-spindle guide, and stands directly beneath the above-mentioned pin; so that, when the rod *E* lifts (through the medium of the tongue-catch) the induction-valve, the latter continues to lift until the tail of the catch *G*, coming in contact with the pin *H*, trips the tongue, and the valve instantly closes, returning to its normal position. The exhaust-valves lie horizontally, and are operated as follows: Upon the shaft *D* are the disks *J*, which are provided with cam-grooves. The rocker-arm *K* carries a friction-roller extending into the cam-groove, the upper arm *L* being attached to the exhaust-valve spindle. To compensate for the circular motion of the arm and the vertical movement of the valve-spindle, the connection between the two is made by the eye of the spindle, containing a slot, in which is fitted a sliding die to which the pin of the arm is fitted. To regulate the amount of compression, it is merely necessary to adjust the position of the disk. The governor is of the ordinary fly-belt type, and is inclosed in a polished casing.

*The Buckeye Automatic Cut-off Engine* is represented in elevation in Fig. 1464. Fig. 1465 is a section of the cylinder, and Fig. 1465 A shows the construction of the governor used. By reference to Fig. 1465, the main valve is seen to be a hollow box, taking steam on the inside, balanced by the exclusion of steam-pressure from the back, and driven in the usual way by an eccentric fast on the shaft. Steam is admitted from the inside of the valve to the cylinder and exhausted into the chest, the reverse of the ordinary operation. The valves are fitted up under steam at 80 lbs., insuring freedom from leakage or cutting from distortion caused by expansion under heat or pressure. The cut-off mechanism consists of a light cut-off valve, working on the inner face of the main valve, the stem passing out through the hollow steel stem of the main valve, and being driven from a loose eccentric on the shaft with a special motion derived from the compound rock-shaft. This loose eccentric is controlled by the governor, Fig. 1465 A, which is a shell fast upon the shaft and revolving with it. In this shell are pivoted two weighted levers, the outer ends of which are linked to the

1465 A.






1466.

flange on the elongated sleeve of the loose eccentric. The centrifugal force developed in the weights throws them outward, and two well-tempered steel coil springs furnish the centripetal force. The system being coupled is independent of gravity, and it is readily seen that the speed determines the position of the weighted arms, which in turn determines the angular advance of the eccentric and the consequent point of cut-off, the range of which is, we are informed, from zero to nearly three-quarters of the stroke.

Fig. 1466 represents an indicator diagram taken from one end of the cylinder of a Buckeye automatic cut-off engine; and the following data, in relation to the engine from which the diagram was taken, were furnished by the Buckeye Engine Company:

Scale of indicator spring, $\frac{1}{40}$; diameter of cylinder, 18 inches; length of stroke, 36 inches; clearance in cylinder and ports at each end of cylinder, 2 per cent. of piston displacement per stroke; diameter of piston-rod, 3 inches; extreme length of cylinder between heads, $44\frac{1}{2}$ inches; length of steam-port, 17 inches; width of steam-port, $1\frac{1}{2}$ inch; revolutions of engine per minute, 98.

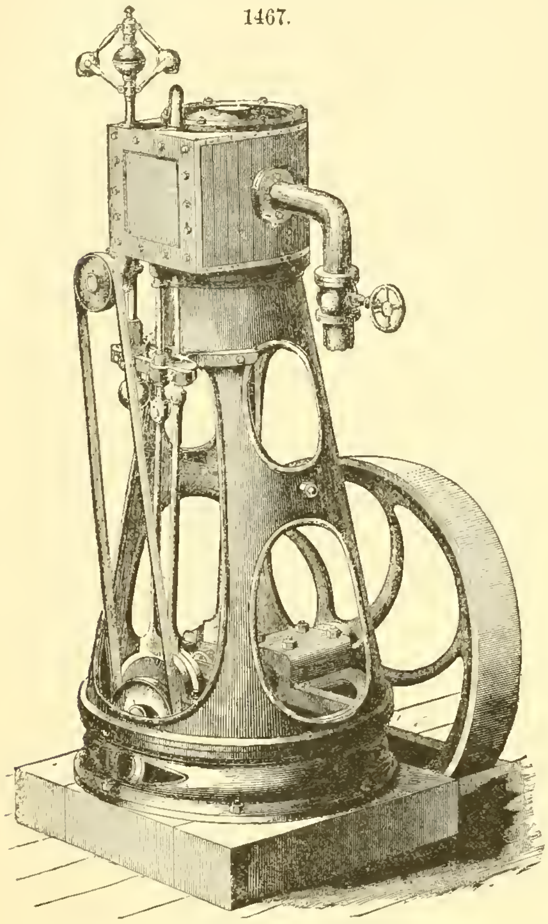
*Data obtained from the Diagram.*—Draw perpendiculars to the *atmospheric line* $a\,b$, at the extremities of the diagrams, produce them below this line a distance equal to $\frac{14.7}{40} = 0.37$ inch, and draw the *perfect vacuum line* $c\,d$ parallel to $a\,b$. Next select a point near one end of the diagram, a little before *release*, and another point near the other end, a little beyond *exhaust closure*. In the diagram under consideration, these points are taken at 0.95 of the forward and return strokes respectively. The length of the diagram is 3.73 inches, so that $c\,n$ is $0.95 \times 3.73 = 3.54$ inches, as is also $d\,i$. Erect perpendiculars to $c\,d$ at the points $n$ and $i$, and draw also the perpendicular $k\,f$ through $f$, at which point *cut-off* has apparently occurred. Make $c\,l$ equal to $0.02 \times 3.73 = 0.07$ inch, and draw the perpendicular $l\,m$, thus increasing the length of the diagram in accordance with the clearance. By measuring the lengths of these several perpendiculars, the absolute pressures in pounds per square inch in the cylinder at the various points can be determined: Initial pressure, $c\,e$, $2.44 \times 40 = 97.6$; pressure at point of cut-off, $k\,f$, $2.28 \times 40 = 91.2$; pressure at 0.95 of forward stroke, $n\,g$, $0.42 \times 40 = 16.8$; pressure at 0.95 of return stroke, $i\,h$, $0.44 \times 40 = 17.6$. The diagram also gives the cut-off in fraction of stroke, $\frac{c\,k}{c\,d} = \frac{0.63}{3.73} = 0.169$, and the real cut-off, $\frac{l\,k}{l\,d} = \frac{0.70}{3.80} = 0.188$. An annular planimeter was used for calculating the diagram, Fig. 1466. This gave the total mean pressure in pounds per square inch $= \frac{\text{area } e\,f\,g\,b\,d\,c}{c\,d} \times 40 = \frac{4.33}{3.73} \times 40 = 46.43$; the mean total back pressure $= \frac{\text{area } e\,h\,b\,d\,c}{c\,d} \times 40 = \frac{1.60}{3.73} \times 40 = 17.16$; the mean effective pressure $= \frac{\text{area } e\,f\,g\,b\,h}{c\,d} \times 40 = 46.43 - 17.16 = 29.27$; and the fraction of the total work that is due to expansion $= \frac{\text{area } f\,g\,b\,d\,k}{\text{area } e\,f\,g\,b\,d\,c} = \frac{2.84}{4.33} = 0.656$.

The only other data needed in the calculations can be obtained from table I. in the article Expansion of Steam and Gases. Thus, from column 10, by interpolation, it is found that the weight of a cubic foot of steam at a pressure of 16.8 lbs. per square inch, represented on the diagram by $n\,g$, is 0.04304 lb.; that the weight at a pressure of 17.6 lbs. per square inch, represented by $i\,h$, is 0.04496 lb.; and by column 6, that the latent heat in a pound of steam, at a pressure of 16.8 lbs. per square inch, is 961.3 units.

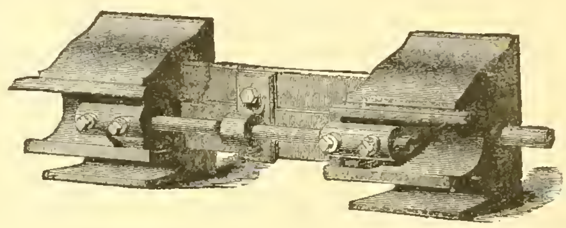
*Calculations from the foregoing Data.*—The effective area of piston is 250.94 square inches. The horse-power of the engine, for 1 lb. per square inch mean pressure, and one revolution per minute, is $\frac{250.94 \times 6}{33{,}000} = 0.045626$; so that the total horse-power is $0.045626 \times 98 \times 46.43 = 207.6$; and the indicated horse-power, $0.045626 \times 98 \times 29.27 = 130.87$. The displacement of the piston in cubic feet per revolution, to 0.95 stroke, including clearance, is $\frac{250.94 \times 72}{1{,}728} \times 0.99 = 10.35128$; so that the number of pounds of steam used per hour, as calculated by pressure near termination of forward stroke, is $10.35128 \times 98 \times 60 \times 0.04304 = 2{,}620$. The steam saved in cushion space in cubic feet per revolution, including clearance, is $\frac{250.94 \times 72}{1{,}728} \times 0.09 = 0.94103$; so that the number of pounds of steam saved per hour by cushion is $0.94103 \times 98 \times 60 \times 0.04496 = 249$. The number of pounds of steam condensed per hour for the total work due to expansion is $\frac{207.6 \times 0.656 \times 1{,}980{,}000}{772 \times 961.3} = 363$. From this it appears that the least possible consumption of steam in pounds per hour by the engine $= 2{,}734$; corresponding to a consumption, in pounds per hour, of $\frac{2{,}734}{207.6} = 13.17$ per total horse-power, and $\frac{2{,}734}{130.87} = 20.89$ per indicated horse-power. The condensing surface in the engine under consideration is approximately 28.7 square feet, viz.: in cylinder sides, 17.5; in cylinder heads and 2 sides of piston, 7.1; in piston-rod, 2.4; in ports, 1.7. Internal condensation may be assumed at the rate of 20 lbs. per square foot of condensing surface per hour, making the total condensation $28.7 \times 20 = 574$ lbs. This will give, as the probable number of pounds of steam consumed by the engine per hour, $2{,}734 \times 574 = 3{,}308$; or at the rate, in pounds per hour, of $\frac{3{,}308}{207.6} = 15.93$ per total horse-power, and $\frac{3{,}308}{130.87} = 25.28$ per indicated horse-power. Dividing the water used per horse-power per hour by 9, it appears that the number of pounds of coal used per hour, in a boiler capable of evaporating 9 lbs. of water per pound of coal, is: least possible, per total horse-power, 1.46; probable, per total horse-power, 1.77; least possible, per indicated horse-power, 2.32; probable, per indicated horse-power, 2.81.

*The Rider Engine*, Fig. 1467.—In short-stroke engines of this class, where the ordinary three-ported valve is generally in use, the main slide-valve is, in its action and in the form of its face side, similar to that of the well-known slide-valve, with the exception that its ends are lengthened to admit of steam-ports or openings being formed outside of the valve proper. These openings or ports are, on the face side of the valve, rectilinear and rectangular to the motion of the valve; that is, they run parallel with the ports in the cylinder, or disposed square across the valve-seat. On the back of this main valve, where the cut-off valve is fitted, these steam-ports are oblique, and at opposite angles to each other, the use of which will be presently explained. The cut-off valve is a sector of a cylinder, with its ends cut off obliquely in opposite directions, so that the extremities or acting ends of the cut-off valve respectively conform to the lines of a right- and left-hand screw of high pitch, corresponding to the obliquity or angle of the steam-ports in the back of the main slide-valve. This cut-off valve just described is fitted into a semi-cylindrical recess in the back of the main slide-valve, and between the spiral openings. It is operated lengthwise by a separate eccentric, to which it is attached in the usual manner, excepting that it has a swivel-joint to permit its partial rotation. A portion of the valve-stem is made square, or sometimes arranged with a "feather," and at this place on the valve-stem is fitted a sector, engaging a rack on the lower portion of the governor-spindle, so that as the governor rises or falls the cut-off valve will partly rotate. Thus the cut-off valve is moved lengthwise by the eccentric, and at the same time has imparted to it by the governor an adjusting motion on its axis. As a consequence of the radial motion imparted by the governor, and the spiral form of the steam-ports and acting ends of the cut-off valve, the distance between the openings and the ends of the valve is varied within very wide limits, the effect being to cut off the steam at any point of the stroke. The arrangement may be compared to a right- and left-hand screw, formed by the shape of the valve ends and the openings. This device is extremely sensitive to the action of the governor, as the rectilinear motion of the eccentric causes the radial or axial movement of the cut-off valve to be effected by the least possible amount of force. This compound motion also highly favors the perfection and durability of the service. In engines of a larger size, where it is desirable to have short steam-passages, the main and cut-off valves are divided through the centre, and each end carried outward (Fig. 1468) to act on the steam-ports of the cylinder at its ends, as is usual with the ordinary slide-valves as commonly constructed.

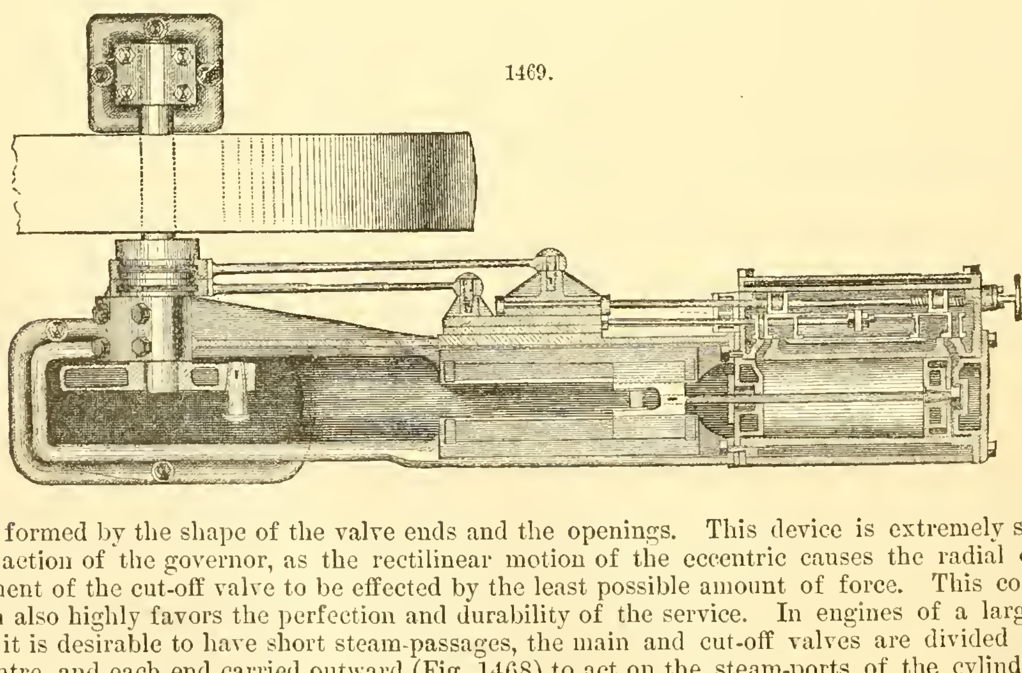
1467.



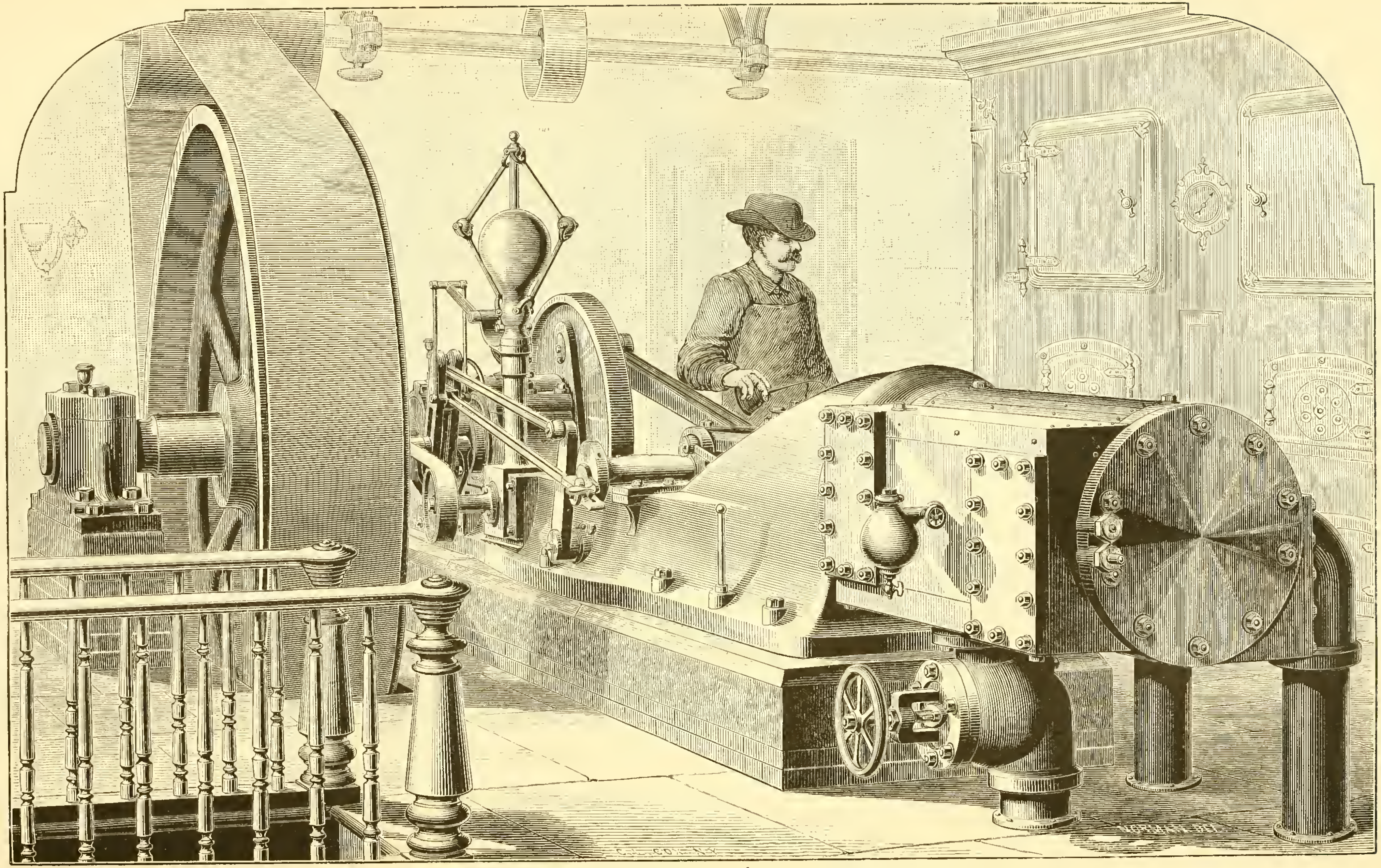
1468.



1469.



The engine illustrated in Fig. 1469 possesses no striking peculiarities, but is a good example of that class of stationary engines in which the cut-off is regulated by hand. There are two cut-off

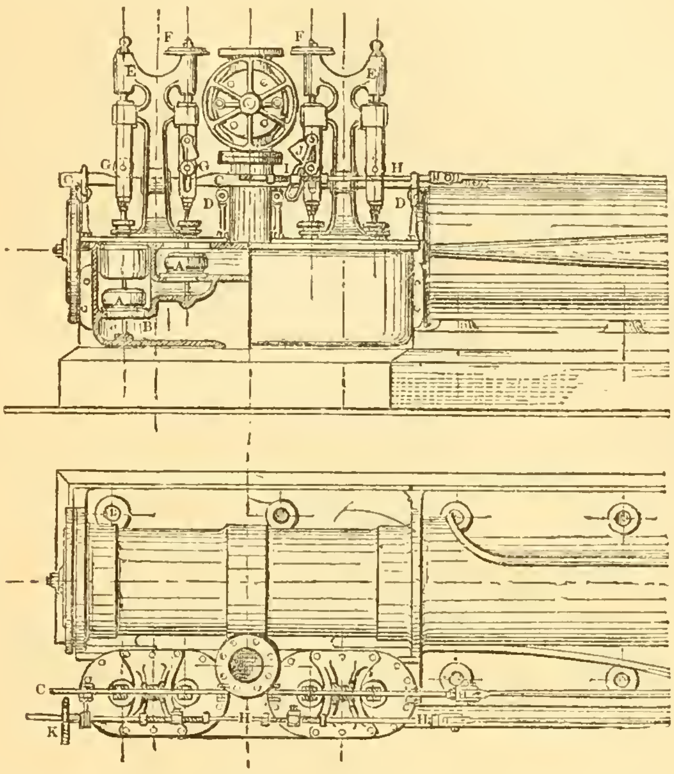


THE PORTER-ALLEN STEAM-ENGINE.

valves on the back of the main valve, actuated by an eccentric having motion coincident with that of the piston; and they are connected to the valve-stem by right- and left-hand screws respectively, so that they can be brought closer together or the reverse by the movement of the hand-wheel shown in the figure.

Fig. 1470 represents a good form of engine built by Messrs. Prescott, Scott & Co., of San Francisco. This engine is provided with the O'Neil valve-motion and cut-off. It will be noticed that the admission of live steam to and the emission of exhaust steam from the steam-cylinder are accomplished by four double-shell valves *A*, resting on the seats *B*, with which both the outer and inner rings have

1470.

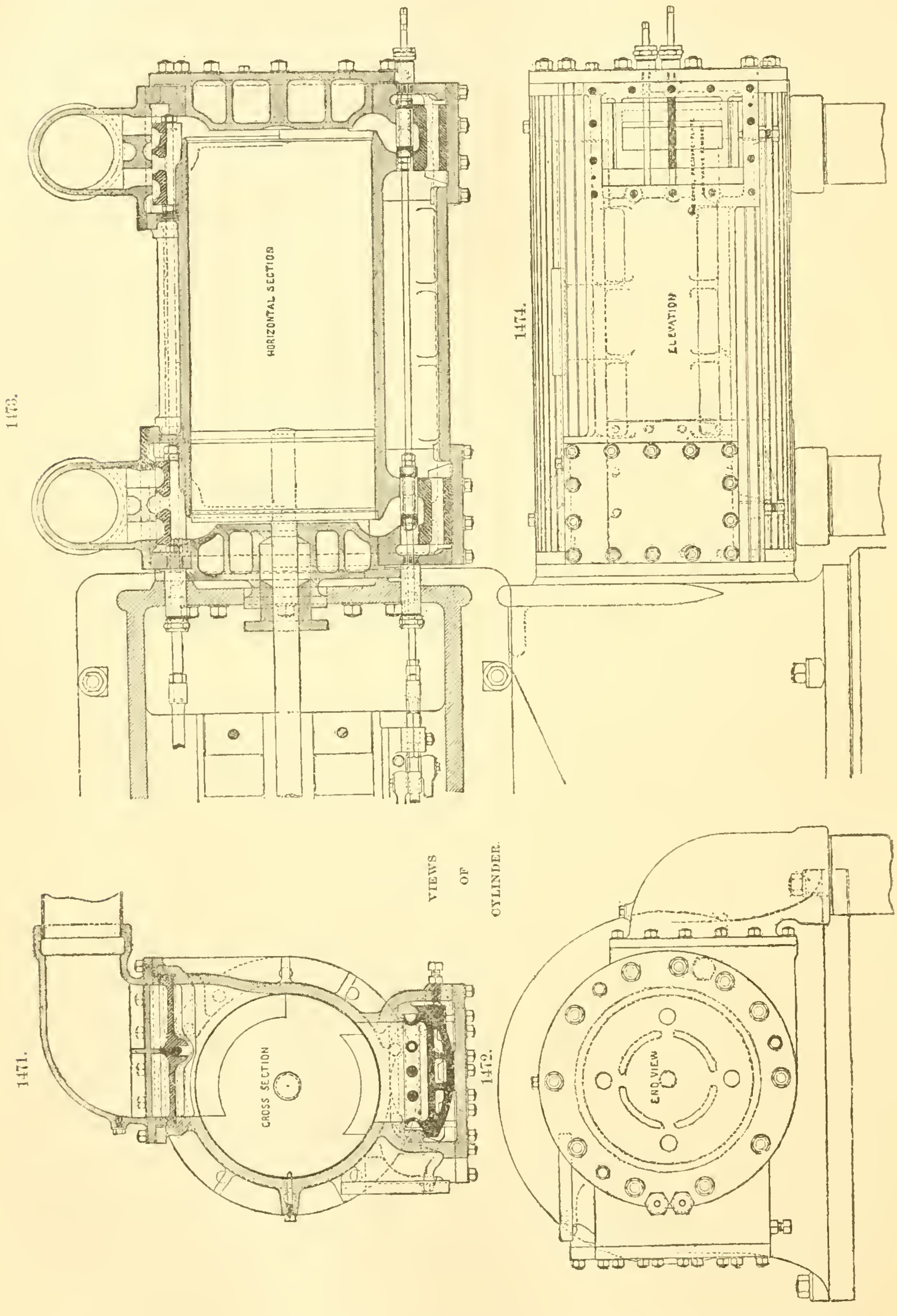



two points of contact. Four circular openings are thus secured when the valves are raised from their seats. The valves are raised by the bar *C*, carried by the rollers *D D*, and worked backward and forward by an eccentric on the crank-shaft of the engine. This bar, which has four inclined planes cut in its upper surface, passes through the slotted valve-stems, which are furnished each with loose rollers *G G*. The reciprocating motion of the bar raises these rollers alternately to the top of the incline, and with them the segments *J* that suspend the valves. Thus at the proper points in the stroke of the engine the four valves are opened. They are reseated by the springs *E E*, while the dash-pots *F F* cushion the valves at the instant of cut-off. The cut-off is operated by the rod *H* connected to the arms *I*, which are attached to the segments *J*, which are oscillated in the slotted valve-stems by an independent eccentric, and supported by the rollers *G G*. When by their oscillation these segments pass the rollers, they lose their support, and with stems and valves suddenly drop. The cut-off is adjusted to any point of the stroke by a hand-wheel *K*, and by the right- and left-hand screws on the cut-off bar, which change the relative position of the segments. By a simple device the whole can be controlled automatically by Scott & Eckart's governor. The advantages claimed for the O'Neil patents are: 1. The lift of the valves is so light that but little power is required to open them. 2. They drop instantly when the cut-off acts, and reseat themselves without pounding. 3. The construction throughout is the simplest possible. 4. Adjustment can be made while the engine is in motion. 5. A much better duty is secured.

*The Porter-Allen Engine* possesses many features of unusual interest, and occupies a deservedly high place among automatic cut-off engines. This engine is illustrated in a full-page engraving and in Figs. 1471 to 1479. All of these figures are reduced from working drawings furnished by Mr. Porter, who gives the following description of the engine:

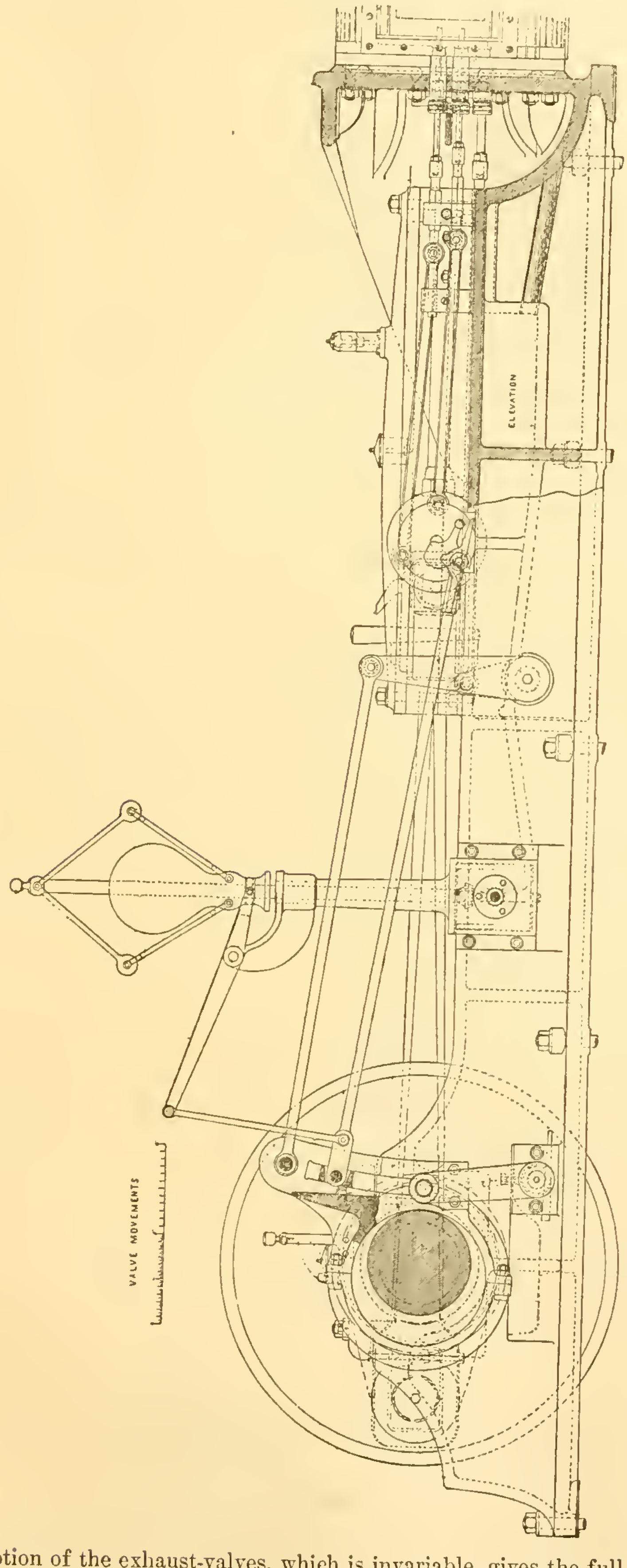
"This belongs to the class of automatic variable expansion engines; but it is distinguished in this, that all its valves have positive movements, which are given by a single eccentric. The valves may be operated with any degree of rapidity, and these engines are designed for a high rate of piston-speed, with moderate length of stroke. In this system of valve-gear, invented by John F. Allen, the eccentric is set on the shaft in the same position with the crank, or so as to reach the termination of its throw when the crank arrives at the line of centres; and the connection of the link is such that its central point, on which it is pivoted, has a motion coincident with that of the piston of the engine—the angular vibration of the line connecting the pivot of the link and the centre of the eccentric coinciding in time and degree with that of the connecting-rod. The openings for admission of steam at the opposite ends of the cylinder are given, as in the ordinary link, by the tip of the link, in opposite directions alternately, beyond the lead-lines, but these are separated by a distance equal to the throw of the eccentric. This link is thus merely a right-angled lever, pivoted on a vibrating fulcrum, with one arm of variable length. When the two arms are of equal length, the cut-off takes

place at the mid-stroke. The release of the steam is, in an engine intended to run in one direction only, effected by separate valves, driven from a fixed point at the extremity of the link. The motion of the link at this point is favorable to the proper action of the valves. The release and compression take place at points near to the terminations of the forward and return strokes, and the movements

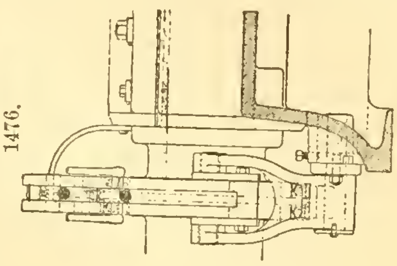



given to the valves in opening and closing are rapid. The governor adjusts automatically the position of the block from which the admission valves are driven, according to the resistance to be overcome, from the mid-point, at which the port is not opened except by the lead given to the valves, to the point at which the steam is cut off at five-eighths of the stroke. Lead is given to the valves by

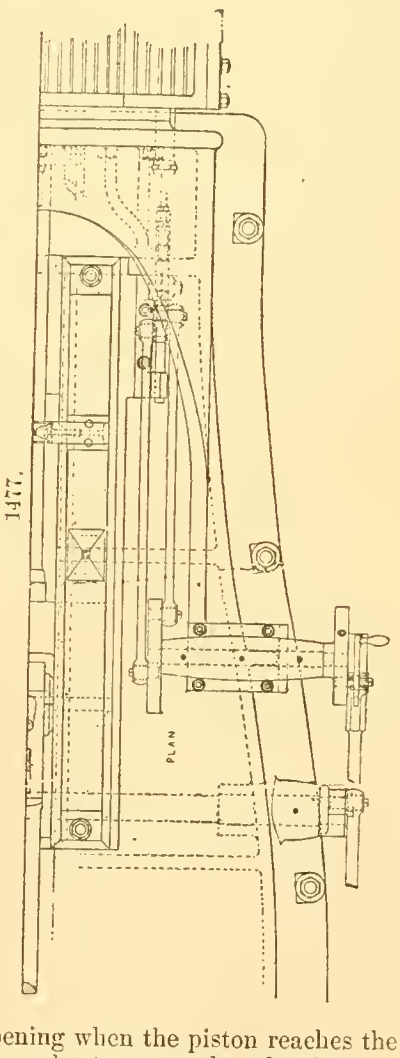
adjusting their position on the stem. The admission of the full pressure of steam, and maintaining it up to the point of cut-off, and its proper discharge, require, in a high-speed engine, corresponding amplitude in the openings. Each valve in these engines opens four passages simultaneously for admission and release. The openings made by the admission valves are further enlarged, and at the same time the idle travel of the valves while their ports are covered is reduced, both in a considerable degree, by the employment of the wrist-motion first applied to slide-valves by Mr. Corliss. The




1475.



1476.

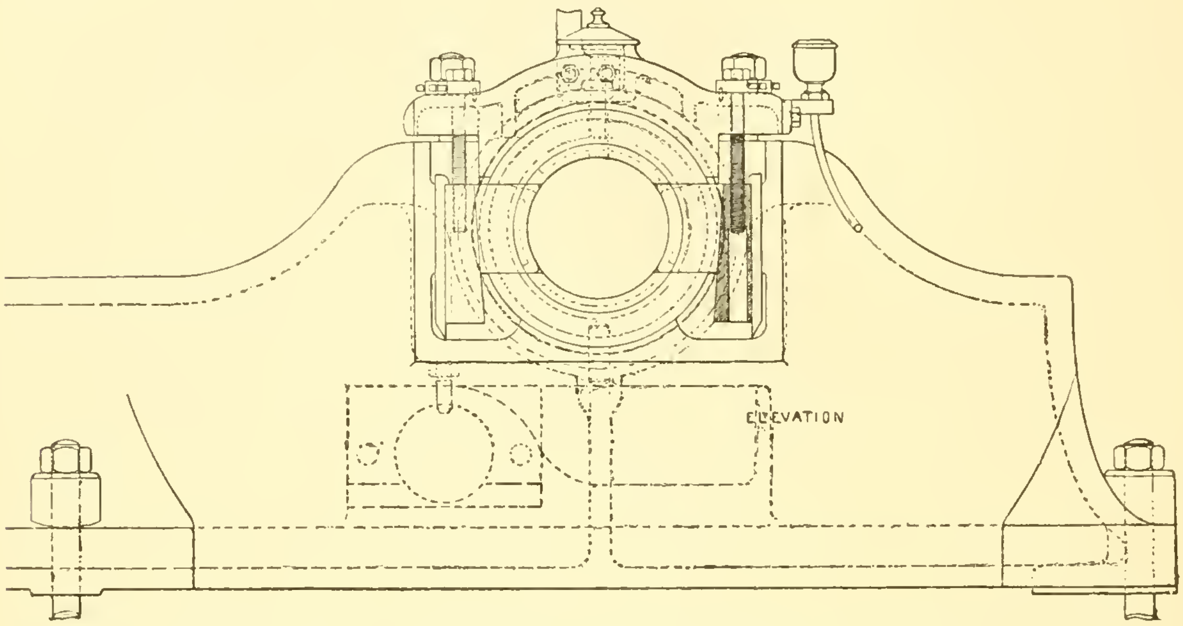



1477.

motion of the exhaust-valves, which is invariable, gives the full opening when the piston reaches the termination of the stroke, and maintains this (their further motions and return merely enlarging two passages while contracting the other two) until near the end of the return stroke, when the port is

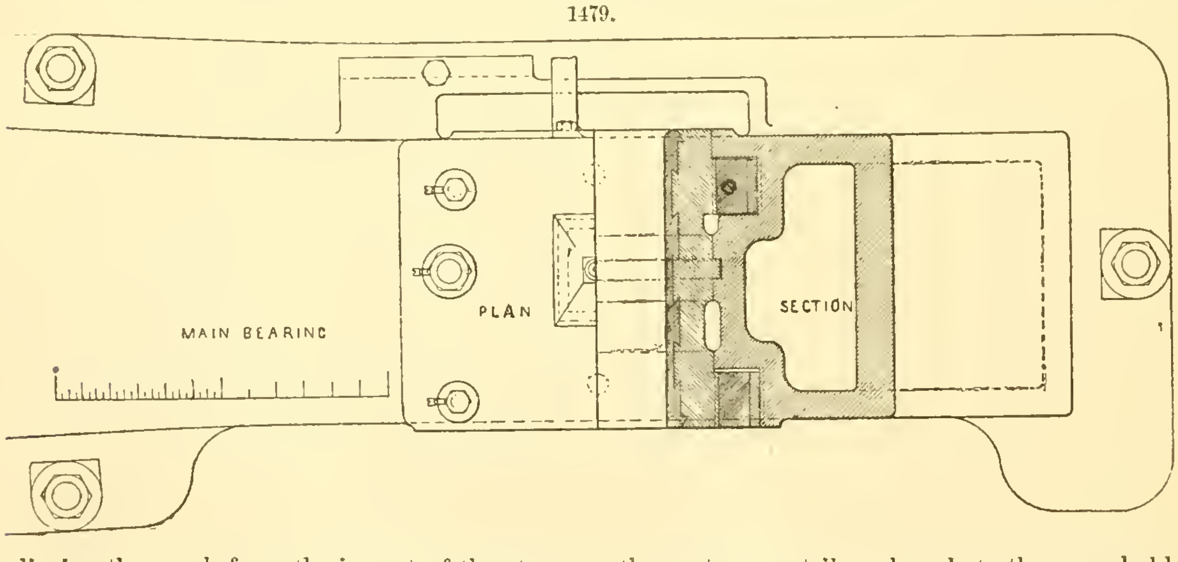
closed by an accelerated movement. The admission valves move in equilibrium between opposite parallel seats. Those at the back of the valve are made adjustable, to compensate for wear, in a manner fully shown in the sectional views of the cylinder. The exhaust-valves work under the pressure in the cylinder. Their seats, the cover of the chamber, and the discharge nozzle are formed in one piece. The principle which is regarded as fundamental in the working of these engines is the action of the reciprocating parts, the piston, cross-head, and connecting-rod, in absorbing the force of the steam at the commencement of each stroke, and giving it out to the crank at its termination. This is founded on the fact that the force required to impart and to arrest the motion of these parts

1478.




is greatest when the piston is on the line of centres, and diminishes from this point to the mid-stroke (as illustrated on page 434). The force varies directly as the weight of the parts, and as the length of the stroke, and as the square of the revolutions per minute; and, while in an engine moving at a moderate speed, with reciprocating parts of ordinary weight, it is quite small, by employing heavy reciprocating parts and high speed, with strokes of moderate length, it becomes easy to absorb, in putting them in motion at the commencement of each stroke, a large proportion of the force of the steam, which is then given out by them to the crank at its termination. This action is of importance chiefly in engines working expansively, tending to equalize throughout the stroke the pressure on the crank which otherwise would be almost wholly applied to it at and near the commencement. These parts of the engine thus perform an office similar to that of the fly-wheel, and, besides partially

1479.




relieving the crank from the impact of the steam on the centres, contribute largely to the remarkable uniformity of rotation which this engine exhibits, and which the small fly-wheels employed would alone seem insufficient to maintain."

The following summary of tests of portable and stationary engines will give a good idea of the best as well as of average results obtained in modern practice. It is proper to remark, with regard to the tests of English portable engines, that they were made with "racing engines," that is, engines constructed especially for the trial, and much superior to the commercial engines furnished by the same makers, and that the firing was done by trained experts; while the other engines were of the ordinary commercial type, and generally managed by attendants of only average skill.

*Summary of Tests of Portable and Stationary Engines.*

| No. for Reference. | Name. | Duration of Trial, in Hours. | Dimensions of Cylinder, in Inches. Diameter. | Stroke. | Revolutions per Minute. | Point of Cut-off from Commencem't of Stroke, in Inches. | Pressure in Pounds per Square Inch. Above the Atmosphere. In Boiler. | Initial. | Mean Effective. | Horse-Power. Indicated. | Net. | Ratio of Net to Indicated. | Pounds of Water per Hour. Per Indicated Horse-power. | Per Net Horse-power. | Pounds of Coal per Hour. Per Indicated Horse-power. | Per Net Horse-power. | No. for Reference. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **Portable Engines at Royal Agricultural Society's Show, Cardiff, 1872.** | | | | | | | | | | | | | | | | |
| 1 | Marshall, Sons & Co. | 4.15 | 8.5 | 12 | 168.8 | 2.04 | 80 | 77 | 31.25 | 18 | 14.3 | .797 | 23.99 | 30.11 | 2.62 | 3.3 | 1 |
| 2 | Clayton & Shuttleworth | 4.84 | 9 | 12 | 113.9 | 2.76 | 80 | 71.5 | 32.1 | .... | 14.3 | .... | ...... | 27.49 | .... | 2.84 | 2 |
| 3 | E. Hayes | 1.48 | 9 | 12 | 122.6 | 7.2 | 63 | 41.6 | 19.6 | 9.1 | 7.6 | .823 | 22.27 | 26.85 | 8.3 | 10 | 3 |
| 4 | Davey, Paxman & Co. | 4.33 | 8.6 | 12 | 114.2 | 1.92 | 80 | 73 | 33.9 | 13.6 | 11.9 | .878 | 28.44 | 32.4 | 2.85 | 3.25 | 4 |
| 5 | Brown & May | 4.13 | 7.3 | 12 | 139.1 | 2.7 | 80.5 | 73 | 29.2 | 10.1 | 9.3 | .92 | 27.55 | 29.97 | 3.02 | 3.29 | 5 |
| 6 | Tasker & Sons | 2.75 | 9. | 12 | 123.7 | 4.56 | 59.5 | 52 | 29.72 | 14 | 12.4 | .88 | 34.16 | 38.66 | 4.36 | 4.94 | 6 |
| 7 | Reading Iron Works | 4.93 | 8.5 | 14 | 138.2 | 3.52 | 80.3 | 72.5 | 37 | 20.3 | 16.8 | .826 | 23.59 | 28.49 | 2.38 | 2.88 | 7 |
| 8 | E. R. & F. Turner | 3.87 | 9 | 12 | 179.2 | 3.84 | 80 | 77.2 | 36.24 | 24.8 | 20 | .803 | 24.07 | 29.85 | 2.9 | 3.63 | 8 |
| 9 | Barrows & Stewart | 2.5 | 9.5 | 13 | 116.1 | 7.8 | 70 | 47.2 | 25.8 | 13.8 | 11.6 | .84 | 34.64 | 41.1 | 4.87 | 5.78 | 9 |
| 10 | Ashby, Jeffery & Luke | 1.8 | 9.5 | 14 | 125 | 2.24 | 80 | 63 | 20.4 | 12.6 | 8.3 | .66 | 40.56 | 61.36 | 4.94 | 7.47 | 10 |
| | **Portable Engines at Cincinnati Industrial Exposition, 1875.** | | | | | | | | | | | | | | | | |
| 11 | Lane & Bodley | 5 | 7 | 12 | 203.3 | .... | 72.3 | .... | ...... | 18.5 | 15.1 | .816 | 40.81 | 50.01 | 6.56 | 8.04 | 11 |
| 12 | Woodsum Machine Co. | 5 | 6.5 | 12.5 | 208.3 | .... | 75.3 | .... | ...... | 12.5 | 10.5 | .836 | 71.46 | 85.52 | 11.43 | 13.67 | 12 |
| 13 | Robinson Machine Works | 5 | 6.5 | 12 | 205.8 | .... | 74.6 | .... | ...... | 15 | 11.6 | .775 | 53.13 | 68.7 | 9.22 | 11.9 | 13 |
| 14 | Gaar, Scott & Co. | 5 | 6.5 | 13 | 188.4 | .... | 74.4 | .... | ...... | 15.4 | 12.3 | .803 | 64.6 | 68.01 | 8.89 | 11.07 | 14 |
| 15 | Brownell & Kielmeier Manufact'g Co. | 5 | 6 | 10 | 197.6 | .... | 74.2 | .... | ...... | 9.9 | 8.3 | .845 | 61.1 | 72.3 | 9.99 | 11.82 | 15 |
| | **Portable Engine at Centennial Exposition, 1876.** | | | | | | | | | | | | | | | | |
| 16 | J. C. Hoadley Co. | 6.03 | 14.6 | 20 | 126 | 3.53 | 120 | 117.6 | 38.49 | 80.3 | 72.7 | .905 | 25.61 | 28.27 | 3.35 | 3.69 | 16 |
| | **Portable Engines at New York State Agricultural Fair, 1877.** | | | | | | | | | | | | | | | | |
| 17 | Porter Manufacturing Co., limited | 4 | 7 | 10 | 141.3 | .... | 72.4 | .... | ...... | .... | 7.4 | ... | ...... | 70.16 | .... | 13.02 | 17 |
| 18 | " " " " | 4 | 7 | 10 | 138.4 | .... | 79.1 | .... | ...... | .... | 9.3 | ... | ...... | 43.22 | .... | 5.74 | 18 |
| 19 | " " " " | 2 | 5.5 | 7 | 190.9 | .... | 91.8 | .... | ...... | .... | 5.2 | ... | ...... | 61.61 | .... | 10.06 | 19 |
| 20 | Fishkill Landing Machine Co. | 4 | 6 | 6 | 238.6 | .... | 119.1 | .... | ...... | .... | 8.9 | ... | ...... | 45.1 | .... | 6.33 | 20 |
| 21 | Mansfield Machine Works | 4 | 7 | 10 | 162.9 | .... | 59.9 | .... | ...... | .... | 7.4 | ... | ...... | 76.61 | .... | 12.69 | 21 |
| 22 | G. Westinghouse & Co. | 4 | 6 | 7 | 260.1 | .... | 69.9 | .... | ...... | .... | 8 | ... | ...... | 63.78 | .... | 9.02 | 22 |
| 23 | E. M. Birdsall & Co. | 4 | 7 | 9 | 204.4 | .... | 65.8 | .... | ...... | .... | 8.3 | ... | ...... | 63.31 | .... | 10.04 | 23 |
| 24 | Watertown Steam-Engine Co. | 4 | 6 | 12 | 184.4 | .... | 89.6 | .... | ...... | .... | 7.1 | ... | ...... | 62.45 | .... | 9.23 | 24 |
| 25 | Frick & Co. | 4 | 7 | 10 | 178.5 | .... | 89.5 | .... | ...... | .... | 6.3 | ... | ...... | 70.32 | .... | 9.68 | 25 |
| 26 | Oneida Iron Works | 4 | 7 | 10 | 182.8 | .... | 85.3 | .... | ...... | .... | 6.6 | ... | ...... | 76.18 | .... | 10.51 | 26 |
| 27 | B. W. Payne & Sons | 2 | 4 | 5 | 227.1 | .... | 91.1 | .... | ...... | .... | 3.3 | ... | ...... | 61.26 | .... | 7.66 | 27 |
| | **Automatic Cut-off Engines at American Institute Exhibition, 1869.** | | | | | | | | | | | | | | | | |
| 28 | Babcock & Wilcox | 8 | 16 | 42 | 60.3 | 7.94 | 81.7 | 76.1 | 31.06 | 78.8 | 68.7 | .872 | 25.48 | 29.23 | .... | .... | 28 |
| 29 | Harris-Corliss | 8 | 16.1 | 42 | 60.3 | 9.49 | 80.5 | 70.9 | 29.73 | 76.6 | 69.1 | .901 | 26.06 | 28.88 | .... | .... | 29 |
| | **Automatic Cut-off Engines at Cincinnati Industrial Exposition, 1874.** | | | | | | | | | | | | | | | | |
| 30 | Harris-Corliss | 8 | 16.1 | 48 | 60.1 | 9.94 | 70.5 | 69.3 | 25.38 | 74.9 | 65.9 | .879 | 29.18 | 33.19 | .... | .... | 30 |
| 31 | John Cooper Engine Manufact'g Co. | 8 | 16 | 30 | 84.3 | 7.83 | 70.3 | 70.1 | 29.18 | 74.9 | 66.6 | .889 | 30.56 | 33.95 | .... | .... | 31 |
| | **Slide-valve Engines, regulated by Throttle, at Cincinnati Industrial Exposition, 1875.** | | | | | | | | | | | | | | | | |
| 32 | Buckeye | 5 | 10 | 14 | 209.8 | 8.75 | 79 | 58.4 | 35.15 | 41 | 36.7 | .896 | 43.15 | 48.16 | .... | .... | 32 |
| 33 | Lane & Bodley | 5 | 9 | 15.6 | 194.7 | 13.57 | 77.9 | 58.9 | 39.06 | 38.1 | 33.8 | .885 | 44.86 | 50.67 | .... | .... | 33 |

Although it has been impossible in the preceding notice to include all the prominent forms of automatic expansion-gear in the market, the distinguishing characteristics of nearly all important varieties have been given. In the accompanying table will be found the principal dimensions of some of the best varieties of stationary engines, which will doubtless be of interest and value to steam-engine users and manufacturers:

*Dimensions of Horizontal Stationary Engines.*

| No. | DETAILS. | Erie City Iron Works. | Jerome Wheelock. | Lane & Bodley. |
|---|---|---|---|---|
| 1 | Arrangement of cut-off.... ................ | Fixed | Controlled by gov. | Fixed |
| 2 | Diameter of cylinder, inches................ | 14 | 14 | 9 |
| 3 | Length of stroke, inches.................... | 18 | 42 | 15.6 |
| 4 | Area of steam-port, square inches........... | 12.375 | 16 (both in one) | 6.2 |
| 5 | Area of exhaust-port, square inches......... | 14.625 | | 11.5 |
| 6 | Clearance in per cent. of piston displacement. | 5.56 | .93 | 6.25 |
| 7 | Kind of valve.............................. | Slide | Modified Corliss | Slide |
| 8 | Diameter of valve-stem, inches.............. | 1.25 | 1.25 | .938 |
| 9 | Stroke of valve, inches..................... | 4.125 | 10, on 8-inch crank | 2.25 |
| 10 | Diameter of piston-rod, inches.............. | 2.125 | 2.5 | 1.563 |
| 11 | " of steam-pipe, inches .................. | 3.5 | 4.5 | 3 |
| 12 | " of exhaust-pipe, inches............ | 5 | 6 | 4 |
| 13 | " of fly-wheel, inches............... | 110 | 144 | 79 |
| 14 | Face of fly-wheel, inches.................... | 7 | 24 | 4.5 |
| 15 | Weight of fly-wheel, lbs.................... | 2,500 | 10,000 | 1,832 |
| 16 | Length of engine, inches.................... | 123 | 264 | 110 |
| 17 | Width of engine, inches..................... | 24 | 120 | 25 |
| 18 | Height of engine, inches.................... | 32 | 120 | 23 |
| 19 | Weight of engine, lbs....................... | 9,500 | 20,000 | 3,592 |
| 20 | Working pressure, lbs. per square inch...... | ........ | 60 | 61 |
| 21 | Revolutions per minute ..................... | 125 | 75 | 200 |
| 22 | Cut-off from commencement of stroke, inches | ........ | ........ | 10.9 |
| 23 | Effective horse-power....................... | 50 | 75 | 54 |

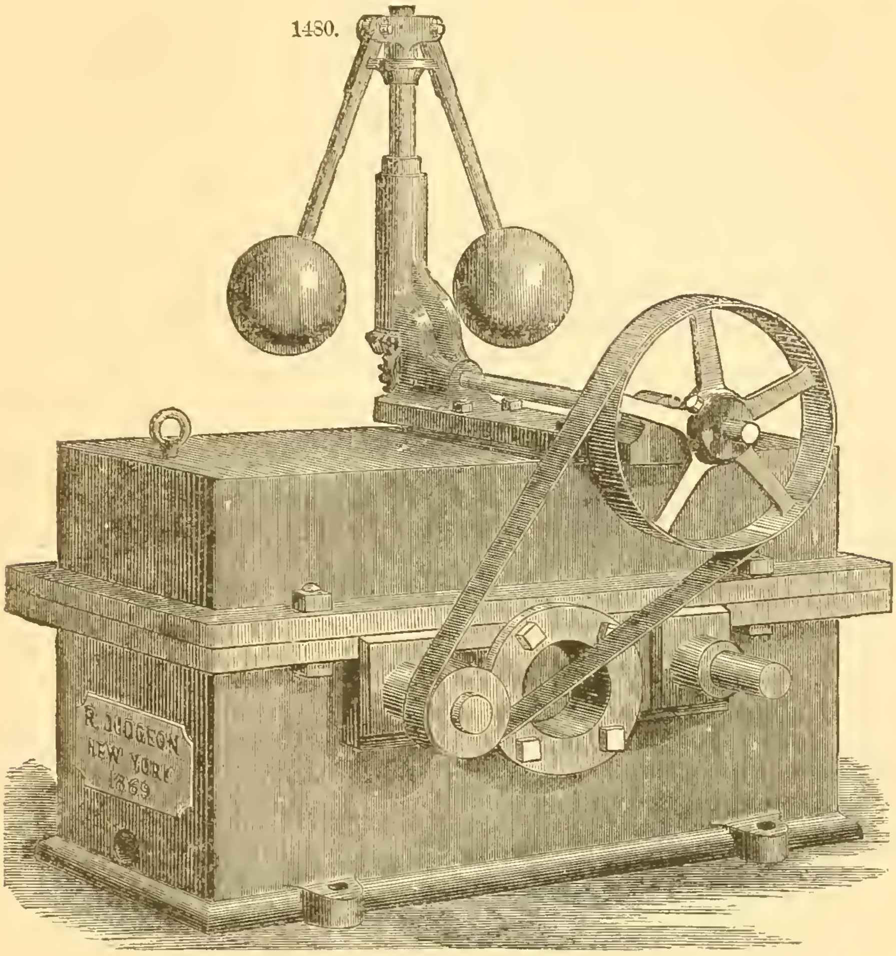
| No. | DETAILS. | Providence Steam-Engine Co. | Porter–Allen. | Watts, Campbell & Co. |
|---|---|---|---|---|
| 1 | Arrangement of cut-off...................... | Controlled by gov. | Controlled by gov. | Controlled by gov. |
| 2 | Diameter of cylinder, inches................ | 26 | 18 | 20 |
| 3 | Length of stroke, inches.................... | 48 | 30 | 48 |
| 4 | Area of steam-port, square inches........... | 35 | 17.5 | 20.81 |
| 5 | Area of exhaust-port, square inches........ | 40.5 | 24.75 | 31.5 |
| 6 | Clearance in per cent. of piston displacement. | 2.7 | 6.67 | 2.08 |
| 7 | Kind of valve.............................. | 4 slides | Allen | Corliss |
| 8 | Diameter of valve-stems, inches............. | 2 and 1 | Steam, 2. each ¾; exhaust, 1. | 1.875 |
| 9 | Stroke of valve, inches..................... | ........ | ........ | ........ |
| 10 | Diameter of piston-rod, inches.............. | 3.75 | 2.625 | ........ |
| 11 | " of steam-pipe, inches............... | 7 | 7 | 5 |
| 12 | " of exhaust-pipe, inches............ | 8 | 7 | 6.5 |
| 13 | " of fly-wheel, inches............... | 216 | 108 | 192 |
| 14 | Face of fly-wheel, inches................... | 32 | 30 | 30 |
| 15 | Weight of fly-wheel, lbs.................... | 23,000 | 5,000 | 20,000 |
| 16 | Length of engine, inches.................... | 354 | 237 | 345 |
| 17 | Width of engine, inches..................... | 156 | 110 | 144 |
| 18 | Height of engine, inches.................... | ........ | ........ | 126 |
| 19 | Weight of engine, lbs....................... | 56,000 | 17,000 | 26,915 |
| 20 | Working pressure, lbs. per square inch...... | ........ | 80 | 80 |
| 21 | Revolutions per minute ..................... | 65 | 140 | 65 |
| 22 | Cut-off from commencement of stroke, inches | ........ | 7.5 | 12 |
| 28 | Effective horse-power....................... | 225 | 200 | 165 |

For works of reference see ENGINES, HEAT. R. H. B.

ENGINES, STEAM, STATIONARY (ROTARY).—It has been said that there is scarcely an engineer of much experience who has not designed at least one rotary engine and one balanced valve, both of which he has afterward abandoned. The number and variety of rotary engines that have been invented is already so great that but few novelties are introduced at present, most modern designs being reinventions. The life of the average rotary engine is so short before it passes into the scrap heap, that but little is known of their performance and capabilities, even when new. An account of almost the only test of rotary engines that was ever published may be found in *Engineering* for Jan. 1, 1875; and although this test has been very severely criticised as being too favorable to the engines, the results are not very flattering to the different designers—the best engine, entirely new, and supplied with unlimited oil, requiring 108 lbs. of steam per net horse-power per hour, and the least economical 398. The ephemeral character of rotary engines is due generally, even when they are well constructed, to mechanical difficulties, which may be summed up in the statement that, so far, no means have been found of packing the pistons so that they shall work without excessive friction, be steam-tight, and durable. There have been numerous projects for overcoming these difficulties, and the literature of the subject is extensive. At present, however, these projects have not assumed tangible form. The reader is referred to Galloway's "History of the Steam-Engine" and Reuleaux's "Kinematics of Machinery," for descriptions and illustrations of nearly every form of rotary engine that has been invented.

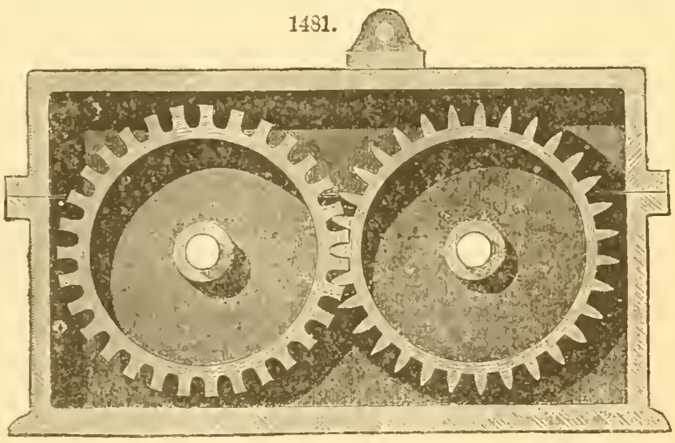
It seems proper, however, to call attention to one example, which differs in many important

1480.

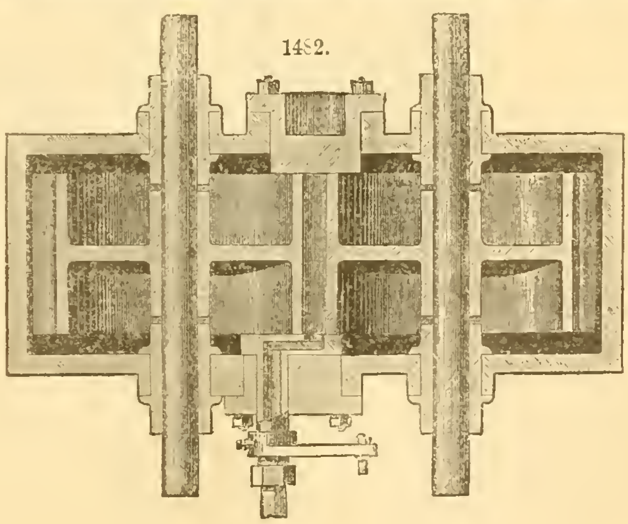



respects from the general form of rotary engine, the differences being of such a character as to overcome many of the practical difficulties ordinarily experienced. Reference is made to Dudgeon's engine, illustrated in Figs. 1480 to 1482, and described as follows in *Engineering* for Nov. 14, 1873:

1481.



1482.



"The principle of the engine and its mode of action will be readily understood if we consider the action of a pair of spur-wheels, such as is shown in Fig. 1481. When such a pair of wheels are working, it is evident that the space inclosed between any given teeth, when situated on the line of centres, is very small, but that as the wheels rotate this space gradually enlarges in capacity, until it becomes thrown open on one side by the teeth falling out of gear. If, then, steam or any other elastic fluid was admitted into the space between any given teeth (escape at the end of the teeth being prevented) when on the line of centres, it would, as the wheels rotated, be expanded, and ultimately be discharged into the air, or into the casing in which the wheels might be inclosed. Practically, this is what occurs in Mr. Dudgeon's rotary engine. Referring to the annexed illustrations, it will be seen that the engine consists of a simple cast-iron casing, formed in two parts, the lower part being fitted with bearings for a couple of shafts, on which a pair of spur-wheels are mounted. These wheels are turned up true on their edges, and those parts of them which are in gear work between a couple of true surfaces, one of these surfaces being formed at the end of a circular plug inserted through

one side of the casing, while the other surface is that of a disk cast in one piece with an eccentric axis, which passes through a loose piece in the side of the casing, as shown in Fig. 1481. It will be seen that the eccentric axis is hollow, and that it communicates with a passage cast in the disk itself, the opening of this passage being situated so that it can discharge steam between the teeth which are in gear. By turning the eccentric axis of the disk, the admission-port can evidently be varied in position, so as to discharge the steam either directly on the line of centres, or within a certain distance above or below that line. We are thus provided with a most simple reversing arrangement; or, if desired, the movement of the disk may be so regulated that the admission-port is always on one side (either above or below) of the line of centres, in which case the movement will vary the degree of expansion. This latter arrangement is that adopted in the particular engine illustrated, a lever on the axis of the eccentric disk being connected to the governor, so that the rise or fall of the governor balls brings the admission-port in the disk-closer to or farther from the line of centres.

"It will be noticed, on reference to Fig. 1481, that the teeth there shown are of somewhat peculiar form, and that they are different on the two wheels. The fact is that they are ordinary epicycloidal teeth, except that those on one wheel are minus the points, and those on the other minus most of the roots or inner portions of the teeth lying within the pitch-circle. The original object of Mr. Dudgeon in adopting this arrangement, instead of having complete epicycloidal teeth on each wheel, was to reduce the spaces inclosed between the teeth when on the line of centres; or, in other words, to reduce clearance. A further investigation of the subject has shown, however, that these spaces are filled by the cushioning of the exhaust-steam; for, the casing in which the wheels revolve being filled with this steam, each pair of wheels as they come into gear inclose a portion, and as the rotation of the wheels continues, the steam thus inclosed is compressed, until by the time it arrives at the line of centres it has reached nearly or quite boiler pressure. This being the case, Mr. Dudgeon is now using complete epicycloidal teeth on both wheels.

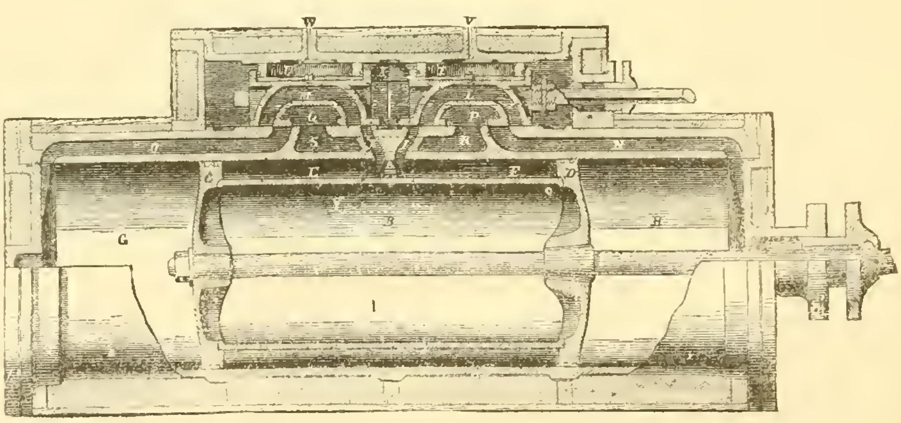
"The engine now working at Millwall has been running over three years without repairs of any kind. Even the side wear has proved to be imperceptible. The engine, it will be noticed, has not a single packed joint about it."

See works for reference under ENGINES, HEAT. R. H. B.

ENGINES, STEAM, UNUSUAL FORMS OF. A great amount of inventive ingenuity has been expended in the devising of steam motors which, either from their uniqueness of form or peculiar mode of action, cannot be strictly classified with ordinary accepted types. Regarding these machines generally, it may be stated that their employment is rarely more than ephemeral, or at best becomes restricted to special uses. The reader interested in them will find scores depicted and described in the United States Patent Office Reports. Among the few instances which exist of engines of this class proving of superior value and utility may be noted those of the Willan and Brotherhood forms of three-cylinder machine. These will be found described under ENGINES, STEAM, MARINE, as their chief application is to the propulsion of small vessels. The engines which are represented in the following engravings have all given reasonably fair results under trial, and they will serve to exhibit some of the best of the unusual forms.

*The Allen Double-Expansion Engine.*—Fig. 1483 shows a section of the cylinder and valves of this machine. The cylinder is made double the length of the stroke, and has a division *A* in the

1483.



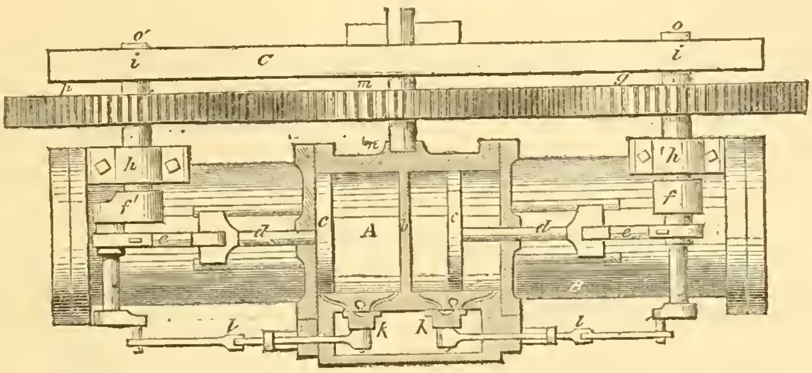
centre, through which the trunk *B* passes. On the ends of the trunk are covers *C D*, held together by the piston-rod. Steam enters first through the port *K* into the annular space *E*. It escapes at the end of the stroke through the port *K*, passes through the passage *M* in the valve and into the port *O*, and so to the end *G* of the cylinder, where it expands. Upon the stroke being again commenced, the steam in *G* passes out through the port *O* into the valve *Q*, being exhausted at *S*. The action at the other end of the cylinder is precisely the same. The division *A* is packed the same as a piston, the rings, however, having a spring inward instead of outward. The valves are balanced by cast-iron rings *T* and *U*, being placed on their backs and kept to the face of the chest by light springs. The tubular openings *V* and *W* communicate with the atmosphere, and are always open. This engine was built in England in 1864. The cylinder was 20 inches in diameter and 30 inches stroke. The trunks were 16 inches in diameter. About 50 revolutions were made per minute, and expansion was carried down to atmospheric line. (See *Scientific American*, xi., 100.)

*Randall's Engine*, Fig. 1484, has a dividing plate *b*, which divides the cylinder *A* into two chambers, in each of which is a piston *c*, having rods *d* which work separate cranks *f* and *f'*. Between

the gear-wheels $p$ and $g$ on the crank-shafts is arranged a third wheel $m$, which meshes into the two driving-wheels and is carried by them. It is "suspended by the teeth and rotated from both sides, maintaining its position almost independently of its bearings, and producing a uniform and steady motion without the use of a balance-wheel." The valves and rods are shown at $k$ and $l$.

*Hurlbut's Spiral-Cam Engine*, Fig. 1485, embodies a curious device for the conversion of recipro-

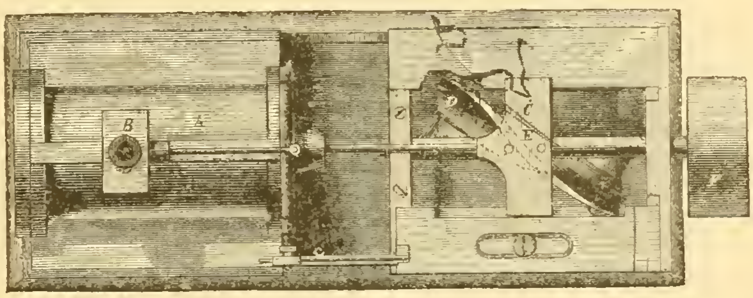
1484.



cating into rotary motion. $A$ is the cylinder, $B$ the steam-chest, $C$ the cross-head, and $D$ the spiral cam. From the lower surface of the cross-head project two pins $E$, which engage with the sides of the cam flanges and impart a rotary motion to the shaft on which the cam is mounted, and through the pulley $F$ to the machinery.

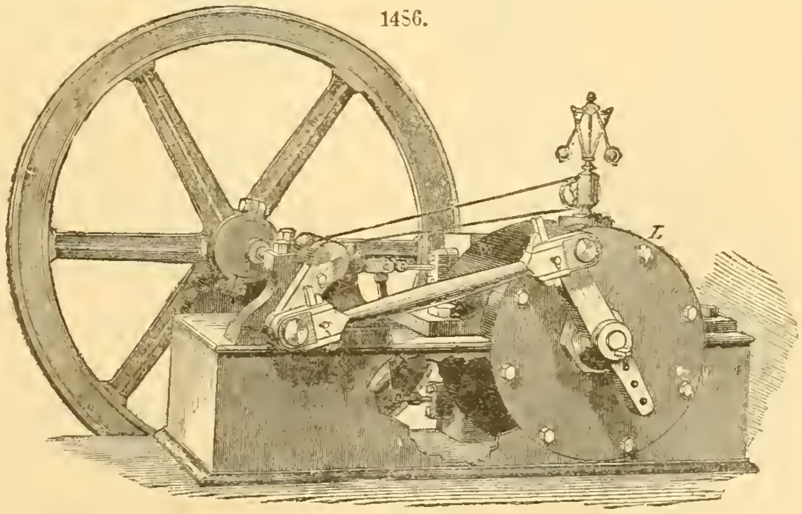
*Runkel's Oscillating-Piston Engine*, Fig. 1486.—This consists of a short cylinder $L$, the central portion of which is occupied by a wheel performing the office of a piston, which makes about half a

1485.



revolution in one direction and then stops and turns back the other way, thus oscillating back and forth. The crank or arm on the end of the axle is made of a proper length in relation to the length of the crank on the fly-wheel shaft to cause a revolution of the latter to each oscillation of the former. The piston-wheel has two rings fastened securely upon it, extending to the inner surface of the cylinder. Two abutments are secured rigidly to the latter and project into the wheel, which revolves against them steam-tight. When steam is admitted the wings are carried nearly against the

1486.



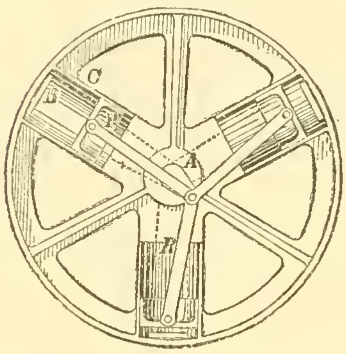
abutments. The valves are then changed so as to admit the steam through the ports from which it had previously been exhausted, and the motion of the piston is reversed.

*The Billings Multicylinder Engine*, Fig. 1487, operates in a manner the reverse of that of ordinary motors, inasmuch as it is the engine that revolves while the shaft and crank are stationary. Instead of one, or even three cylinders being employed, as many may be used as can be grouped around the rim of the fly-wheel without causing too great complication of parts. Dead-centres are, therefore,

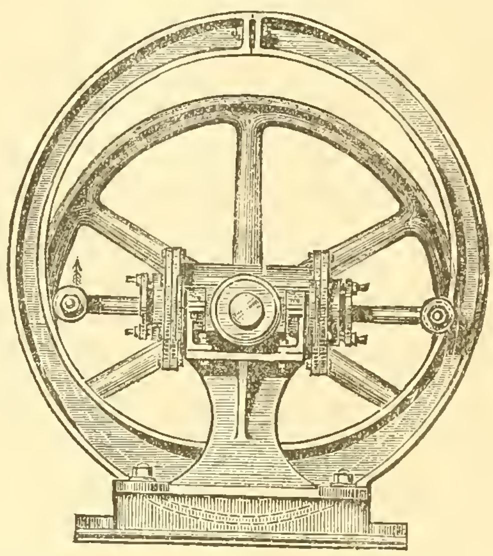
non-existent; and the machine, paradoxical as it may seem, reduces itself to a self-rotating pulley-wheel. *A* is the stationary crank, *C* is a light wheel, and the three cylinders grouped symmetrically about the latter furnish the necessary weight at the rim; the cylinders take steam at the rear end only, *B* being the steam-port, and the dotted lines indicating the steam-passages.

*The Comber Rotary Engine.*—Fig. 1488 represents a curious form of engine devised by Mr. W. A. Comber of Birmingham, England. The action consists in each end of the piston being alternate-

1487.



1488.

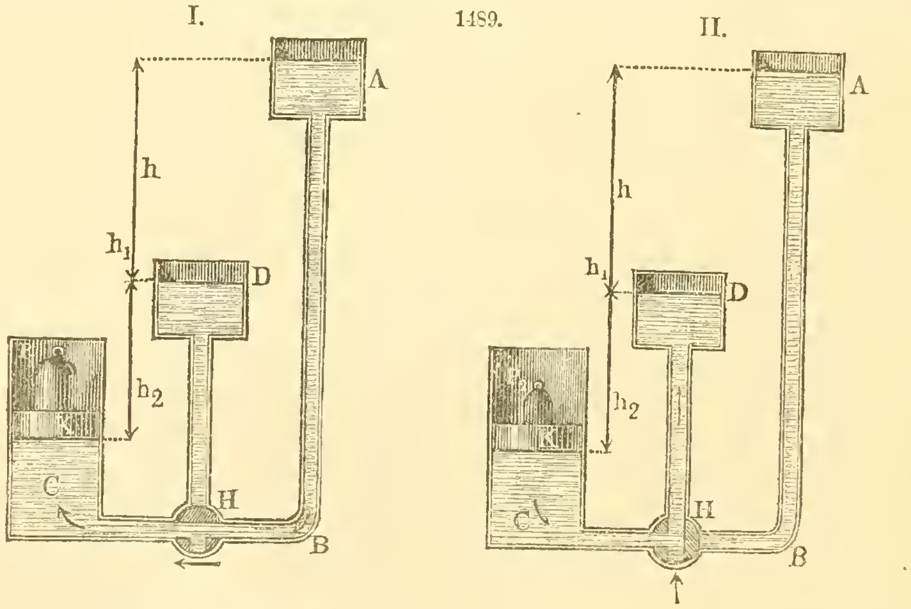


ly propelled down an inclined plane, the curve of which, it is claimed, causes the force of the steam to be almost constant during the whole of the stroke. The cylinder-ports, which serve the double purpose of inlet and outlet, are prolonged into a hollow solid-ended trunnion, turned slightly taper, and surrounded by a divided chamber communicating with the steam-pipe on one side and the exhaust-pipe on the other, and so arranged that the revolution of the cylinder causes the ports to be changed alternately from steam to exhaust at the end of each stroke, any proportion of cut-off being attainable. This chamber, which also serves as a bearing, is held by two brackets surrounding its two pipe branches, which are capable of adjustment in all directions. A horizontal spring governor (not shown) may be attached to the trunnion end and work a governor-valve attached to the steam-inlet flange. A trunnion or flange is cast on the other side of the cylinder, to which is attached a wrought-iron shaft turning in an ordinary bearing for taking off power.

ENGINES, TRACTION. See Engines, Steam, Portable and Semi-Portable.

ENGINES, WATER-PRESSURE. In a motor of this class, water under pressure is admitted to a cylinder, and moves the piston, being allowed to escape on the completion of the stroke. Such engines may be either single- or double-acting. In the single-acting water-pressure engine, the water moves the piston only in one direction, and it is caused to make the return stroke by its own weight,

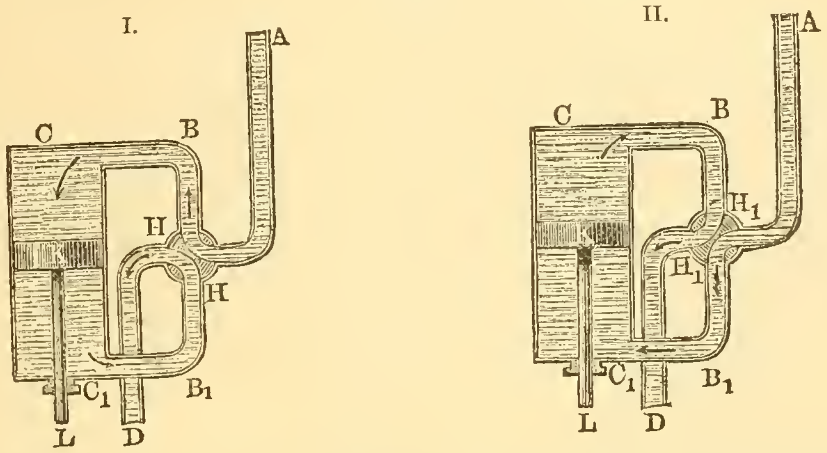
I. 1489. II.




or some added weight if necessary; while in the double-acting engine the water is admitted on both sides of the piston alternately. The pistons of water-pressure engines are generally packed with leather rings, so arranged as to be forced out against the sides of the cylinder by the pressure. The principal parts of the water-pressure engine are, as may be seen from Fig. 1489, the following: *A* is the reservoir or supply-cistern, *A B* the supply-pipe; *C* is the working cylinder, in which the water performs its work by forcing upward the loaded driving-piston *K;* and *H D* is the discharge-

pipe. In the connecting-pipe $B\ C$, which joins the working cylinder with the supply-pipe, is situated the regulator, which in this case is a cock with a T-shaped channel, which serves to unite or to disconnect the supply-pipe and the working cylinder. In the first case, the water forces the piston, with its load $P_1$, upward, and in the second case the water beneath the piston, cut off from the supply-pipe, returns through the cock and is discharged by the pipe $H\ D$, while the piston, now unloaded, descends. There are single- and double-acting engines, and also engines with one and with two cylinders. In the single-acting engine which is shown in Fig. 1489, the piston is moved by the water in one direction only; in the opposite direction its own weight, or an added weight $P_2$, is the moving force. In the double-acting engine, on the contrary, the downward as well as the upward motion is occasioned by the force of the water. Fig. 1490, I. and II., shows the arrangement of such an engine. From this figure is to be seen how the motive water passes first (I.)

1490.

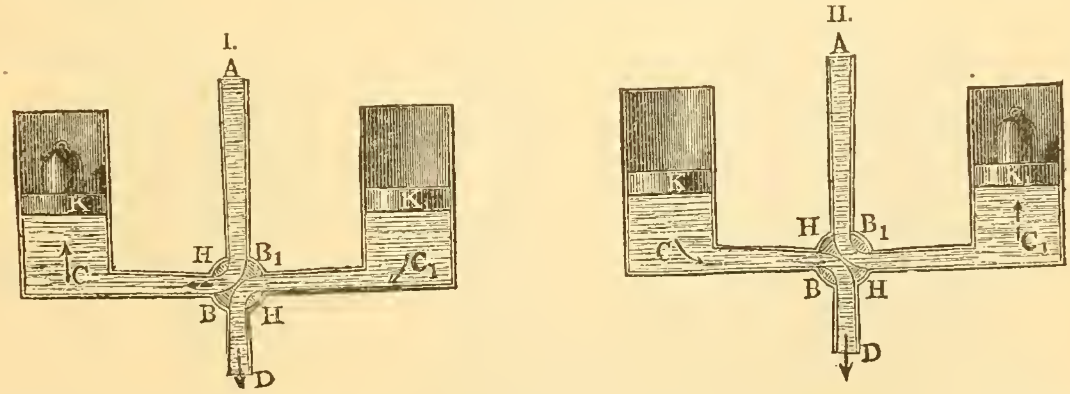



through $A\ B\ C$, forces the piston $K$ downward, and thus drives the water beneath through the passage $C_1\ B_1\ D_1$, and second (II.) through $A\ B_1\ C_1$, forcing the piston upward, and the water above out through $C\ B\ D$.

The water-pressure engines thus far described have but one cylinder. Fig. 1491 represents an engine with two cylinders. Here, while the motive water $A\ B\ C$ forces the piston $K$ upward (I.), the piston $K_1$ descends, and the dead water beneath passes off through the passage $C_1\ B_1\ D$; and, again (II.), while the motive water causes $K_1$ to ascend, $K$ descends, and the dead water passes off through the discharge-pipe $D$.

*Regulator.*—The regulator is, as it were, the soul of a water-pressure engine; by it the machine is enabled to perform its work without interruption. It is composed essentially of two principal parts, one of which alternately shuts the water from or admits it to the working cylinder, and the other is

1491.



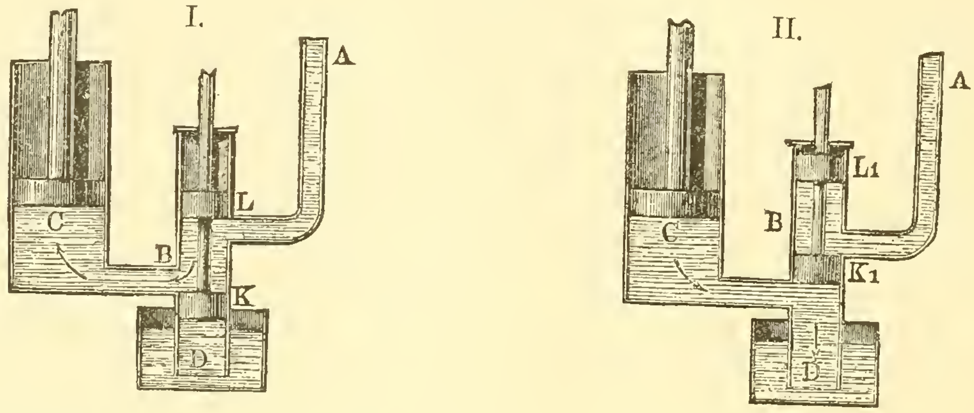

necessary to connect the first with the engine proper (with the piston-rod), so that no outside force will be necessary to work it. We can very well call the first mechanism the inner and the second the outer gear or regulator. As regards the inner regulator of a water-pressure engine, we have to speak especially of the *piston regulator*. Fig. 1492, I. and II., shows the arrangement of a piston regulator for a single-acting, single-cylinder engine. $A$ is the supply-pipe, $C$ the working cylinder, $B$ the cylinder inclosing the regulator-piston or the regulator-cylinder, $D$ the discharge-pipe, $K$ the regulator-piston, and $L$ the so-called counter-piston, which only serves, by creating a counter-pressure, to make the movement of the regulator-piston or rod easier. When the regulator-piston $K$ is in its lowest position (I.), the working cylinder is in connection with the supply-pipe, and the driving-piston can only ascend. When, on the contrary, it is in its highest position (II.), the regulator-piston $K_1$ shuts off the water in the supply-pipe, and that which is beneath the piston is forced out at $D$.

The arrangement of the regulator-piston for a double-acting or for a double-cylinder engine may be seen from Fig. 1493, I. and II. Here $A$ is the supply-pipe, $C$ the connecting pipe for one cylinder

and $C_1$ (I.) that for the other, $D$ the discharge-pipe for the one and $D_1$ that for the second. It is seen from I. how the piston, in its upper position, admits the water to $C$, and the dead water from $C_1$ flows through $D_1$ into $E$; whereas, at the lower position of the piston, the water is turned into $C_1$, and the water shut off in $C$ may flow through $D$ into $E$.

*Kinds of Regulators.*—In single-acting engines, and especially in those which have only a rectilinear motion, it is not possible to connect the regulator directly with the motive mechanism, or to make the motion of the regulator-piston rod depend directly upon that of the driving-piston rod, since then, at the moment when the regulator-piston or valve closes the connection between the working and the regulator-cylinders, not only the driving-piston, but also the regulator-piston connected with it, come to a state of rest. In order that the regulator-piston may be enabled to move through the rest of its stroke after the driving-piston has stopped, it is necessary to use an intermediary apparatus, which only acts upon the regulator-piston when the driving-piston is at rest.

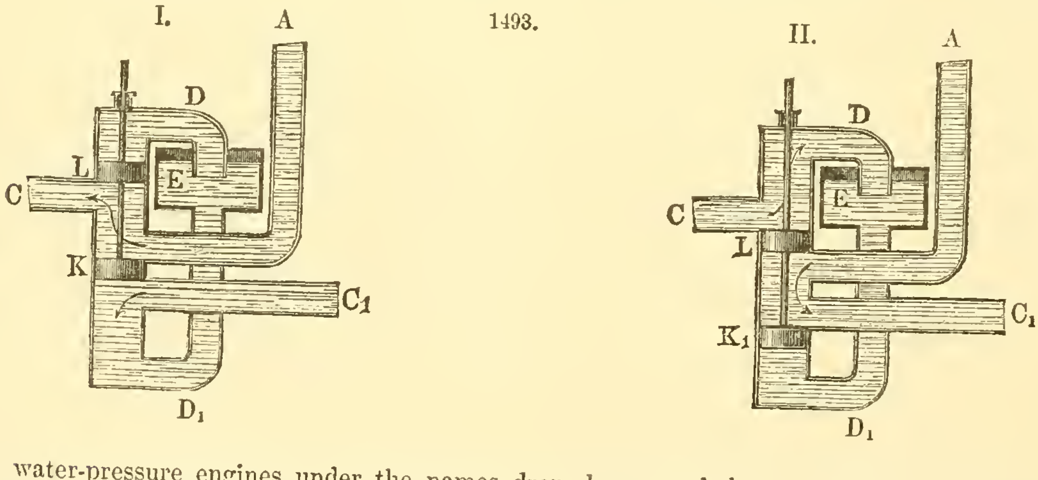
1492.




This apparatus may consist of the following essentials: (1) of a *weight*, which is raised by the driving-piston during its up-stroke, and is let fall at the moment it stops, after making the stroke; or, (2) of a *spring*, which is brought into tension during the movement of the driving-piston, and let go at the end thereof; or, finally, (3) of a second or *auxiliary water-pressure engine*, which is regulated directly by the motive mechanism, and whose driving-piston moves the regulator-piston rod of the principal machine, while the driving-piston of the latter is traversing the last portion of its stroke and for a short time comes to rest. We have, therefore, to distinguish from each other the weight regulator, the spring regulator, and the water-pressure regulator.

The *weight regulator* consists chiefly of a mechanism by means of which the motive engine during its movement raises a weight, which, by falling at the moment when the working cylinder is closed by the regulator cock or piston, etc., moves this regulator through the second part of its prescribed stroke, and completes in this way the regulation. The weight regulator is used in the older and im-

1493.



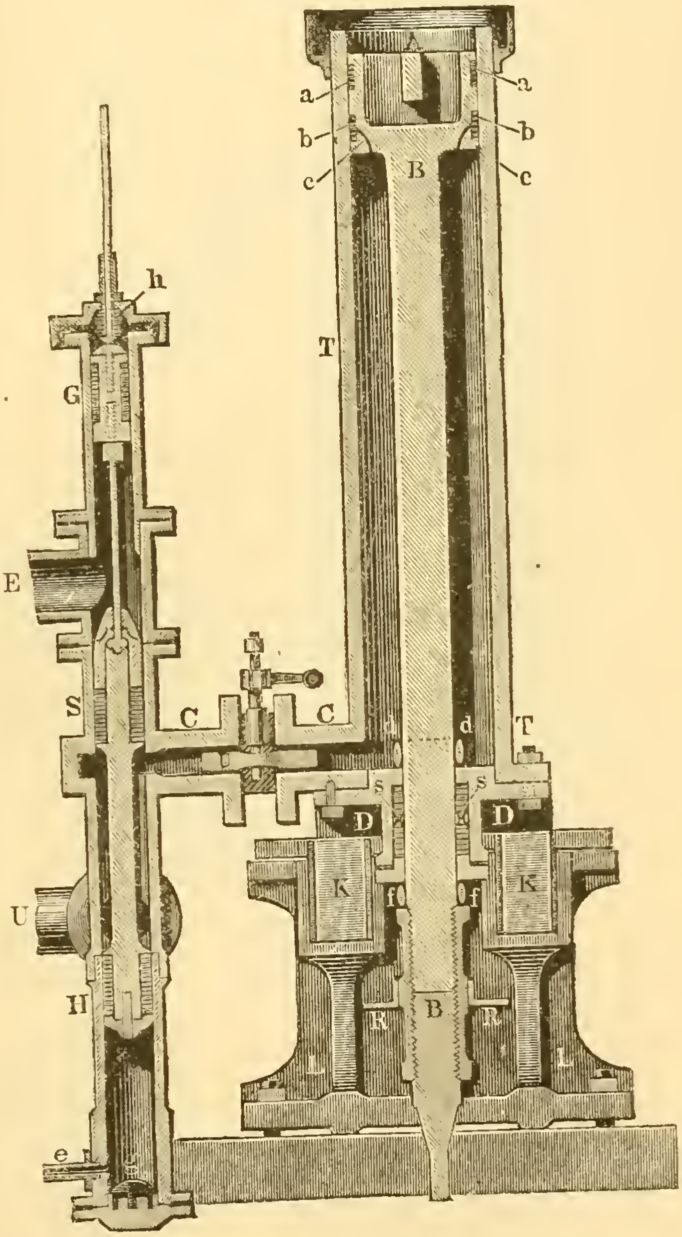

perfect water-pressure engines under the names drop, hammer, balance, pendulum regulator, etc. In modern times, weights are also used with valve regulators, in such a manner that the motive engine opens the one while the falling weight closes the other valve. The arrangement of such a weight regulator is quite the same as in the case of steam-engines with valve regulators. This system consists essentially of several levers in combination with a pawl or ratchet, whence it is also sometimes called a *lever* or *spring-catch regulator*.

*Regulator-Cylinder.*—In the larger machines of modern construction, the regulator and counter pistons of the principal engine, and the driving-piston of the auxiliary engine, are placed in one and the same pipe, the so-called *regulator-cylinder*, after the pattern of Reichenbach's engine in Bavaria; and in some machines, even, the counter-piston performs the function of driving-piston of the auxiliary engine, which is a great simplification. The simplest construction is that shown in Fig. 1494, and used in several Freiberg machines. $S$ is the main regulator, and $G$ the counter and auxiliary driving-piston; $C$ the connection with the principal working cylinder, and $E$ that with the supply-pipe, and $A$ the discharge opening for the motive water; finally, at $e$ is the connection with the regu-

lator of the auxiliary machine, which here consists of a cock. The piston $G$ is larger than $S$; therefore the regulating mechanism $S$ $G$ descends as soon as the motive water is admitted through $e$; and, on the contrary, it ascends, under the action of the upward force on $S$, as soon as $e$ is closed. By this a certain quantity of regulating water is consumed for each stroke from the motive water, which quantity depends on the space traversed by $G$ in its ascent or descent, and which for this construction is not very small, since the piston $G$ should have a section at least as large again as that of the piston $S$, which again is not made smaller than the supply or connecting pipes.

In the regulator of the machine at Clausthal, shown in Fig. 1495, this consumption of regulating water is smaller, as here there are three pistons: the main regulator-piston $S$, the counter-piston $G$, and the auxiliary driving or reversing piston $H$, the last being smaller than the first. The regulating water is here brought into the regulator-cylinder by the pipe $e$, and the regulation of this water is effected by a small cock, through which the water passes before reaching $e$, and through which it is also drawn off after the complete revolution. The movement of this cock is brought about by a

1495.




1494.

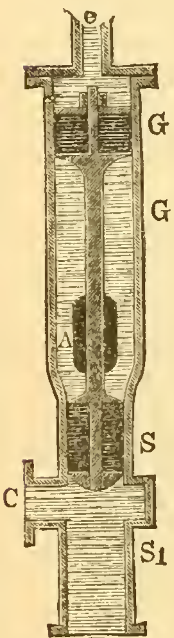


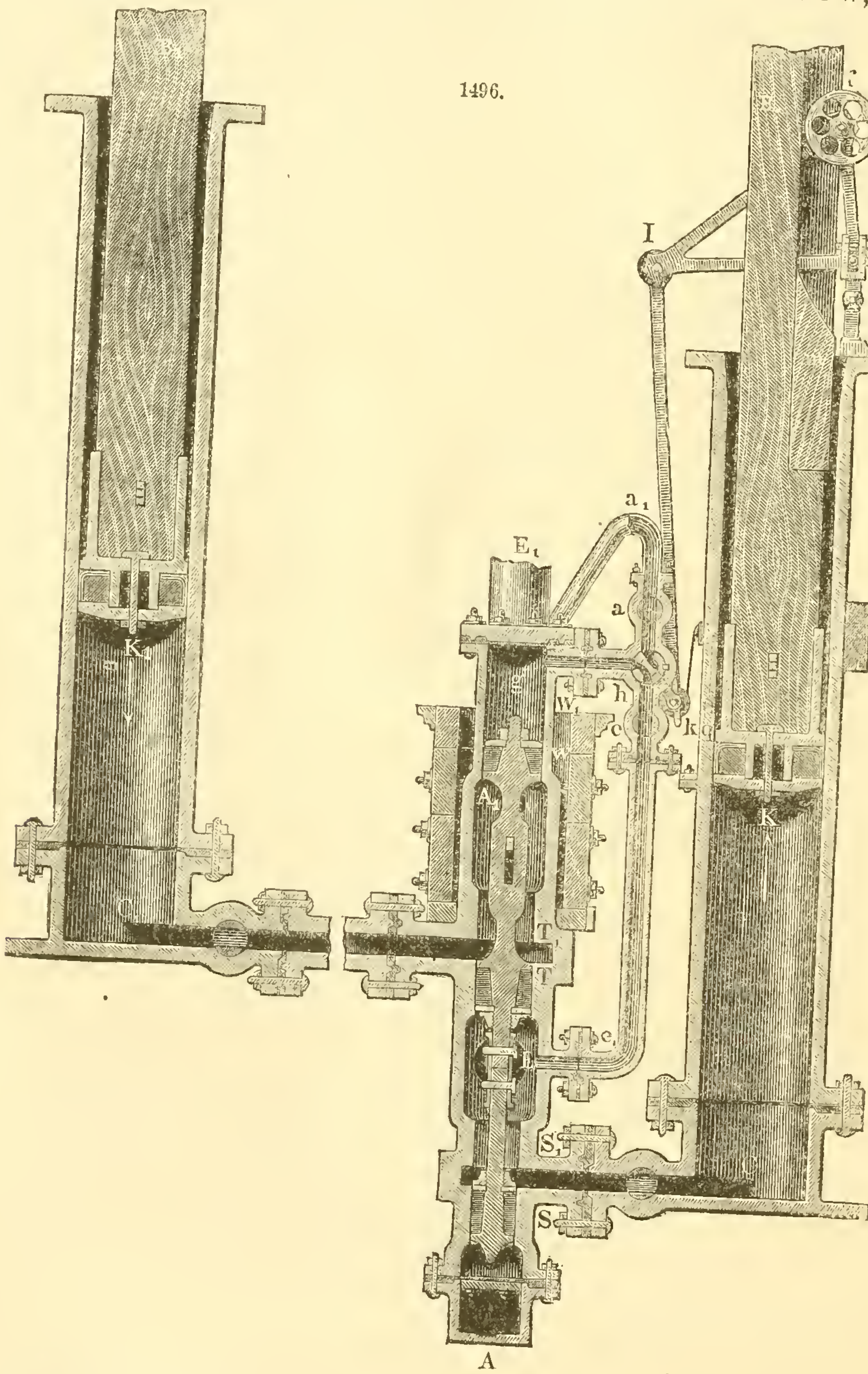

plate fastened to the driving-piston rod, which turns now to the one side, now to the other, by means of two curved knee-formed arms, an arbor connected with the cock. The water-pressure engine at Clausthal has a fall of 630 feet, a piston diameter of 17 inches, and a length of stroke of 6.21 feet, and makes four strokes per minute.

*Double-Cylinder Water-Pressure Engine.*—The arrangement and working of a double-cylinder water-pressure engine is shown clearly in Fig. 1496, which is a vertical section of the machine at the "Alte Mordgrube" in Freiberg. Here $C$ $K$ and $C_1$ $K_1$ are the two working cylinders, $K$ and $K_1$ the driving-pistons, $S$ and $T$ the two regulator-pistons, and $W$ the reversing or auxiliary piston. $S_1$, $T_1$, and $W_1$ denote the positions which these pistons assume at the change of the motion of the driving-pistons. Further, $E$ is the opening of the supply-pipe $E_1$ $E$ into the regulator-cylinder, $C$ $S$ the connecting pipe for the first and $C_1$ $T$ that for the second, $A$ the discharge opening for the first and $A_1$ (almost hidden by the regulator-piston rod) that for the second working cylinder. The two piston-rods $B$ $K$ and $B_1$ $K_1$ are connected by an equal-armed lever or so-called walking-beam (not

shown in the figure), so that the ascent of one causes the descent of the other. It is easily seen, therefore, that at the lower position of the regulator-piston, as represented, the motive water passes through $E\ S_1\ C$ and drives the piston $R$ upward; the piston $K_1$, on the contrary, descends, and the dead water passes out through $C_1\ T_1\ A_1$.

The regulation of the auxiliary machine is effected by the cock with double bore, already described, which is represented at $h$ in Fig. 1497, in elevation in I. and in section in II. This cock is in connection with the supply-pipe by the pipe $c\ e_1$, and with the regulator-cylinder by the pipe $g\ h$. At one position of the cock $h$, the motive water passes through $E\ e_1\ e\ h\ g\ W$, and presses the reversing piston $W$ downward; and at the opposite position the motive water is shut off from $W$, and therefore

1496.



the ascent of $W$, the return of the regulation water through $g\ h$, and its discharge through $a\ a_1$ are possible. In order that, during the shutting off of the motive water from $W$, the regulator-piston and connection may ascend and descend when it is again admitted, it is necessary, however, that the regulator-piston $T$, upon which the water acts from below, shall have a greater area than the piston $S$, upon which the water presses downward, and that the reversing piston $W$ shall have a large enough cross-section, so that the water-pressures on $W$ and $S$ together shall be greater than the opposite pressure upon $T$.

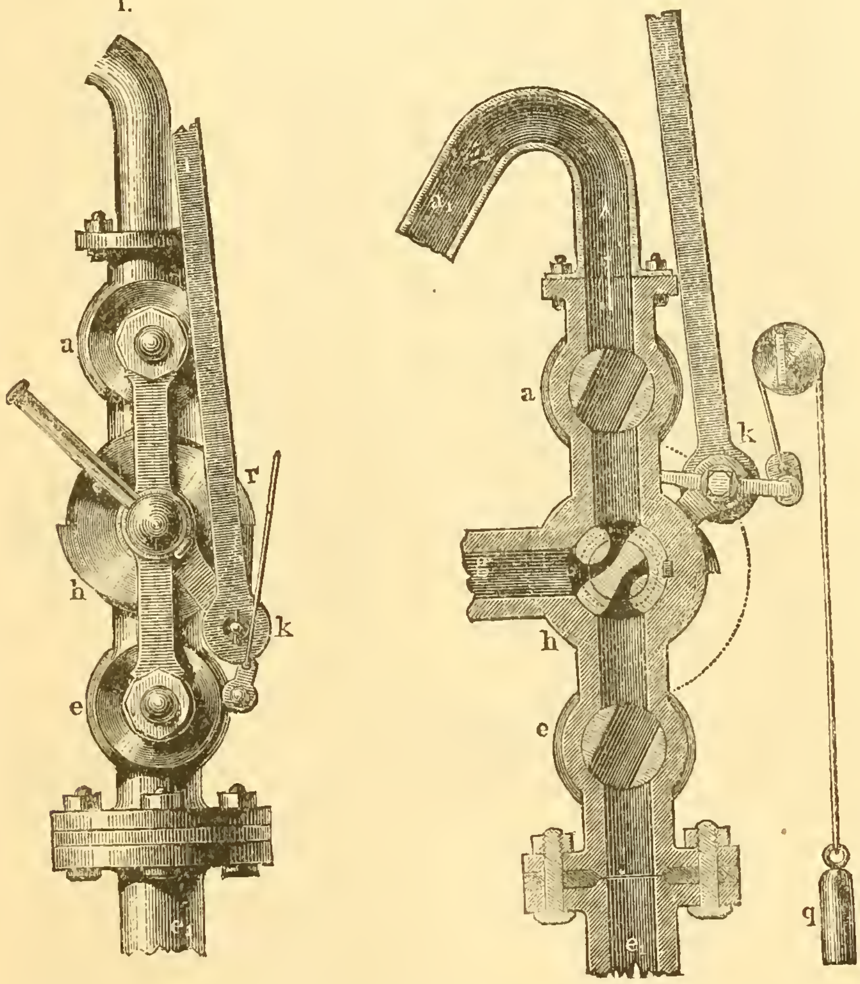
Finally, for the outer regulator of this machine, we have the following mechanism: $r$ is a regulator-wheel having four teeth, $r\ k$ a ratchet, $k\ l$ a rod, $l\ c\ f$ an angle-lever with the friction-wheel $f$ (see Fig. 1496), and $m$ and $m_1$ (the last not shown in the figure) are two oppositely-placed wedges

fastened to the driving-piston rod *B K*. The ratchet *r k* is, moreover, connected with the axis of the cock by arms, and is supported in the teeth of the little wheel *r* by a small counterpoise *q*.

*Single-Cylinder Water-Pressure Engine.*—One of the finest and most complete water-pressure engines is stated by Weisbach to be that at Huelgoat, in Brittany. It is a single-acting, single-cylinder engine, but beside it stands another machine exactly similar. From Fig. 1498 the arrangement and manner of working may be seen. $C\ C_1$ is the working cylinder, $K\ K^1$ the driving-piston, and $B\ B_1$ the driving-piston rod, which passes through the stuffing-box *b*. While in the previously described machine the packing consists of one broad piece of leather, in this one, as may be seen in the figure, a piece of leather is inserted in the piston and another piece also screwed on. The regulator-cylinder *A S G*, at one side, is connected with the working cylinder by the connecting pipe *C D*; the supply-pipe enters it at *E*, and the discharge-pipe leads out of it at *A*. The regulator-piston *S*, shown in the middle position of the down stroke, is connected with the larger piston *T* by the rod *S T*; the whole apparatus, therefore, is forced upward by the extra pressure of the motive water on *T*, unless a third force prevents. This third force is obtained by introducing the motive water above the piston *T*, through the pipe $e_1\ e\ f$; but in order to make the use of only a small quantity of water necessary during the descent of the mechanism occasioned thereby, the hollow

1497.

I. II.



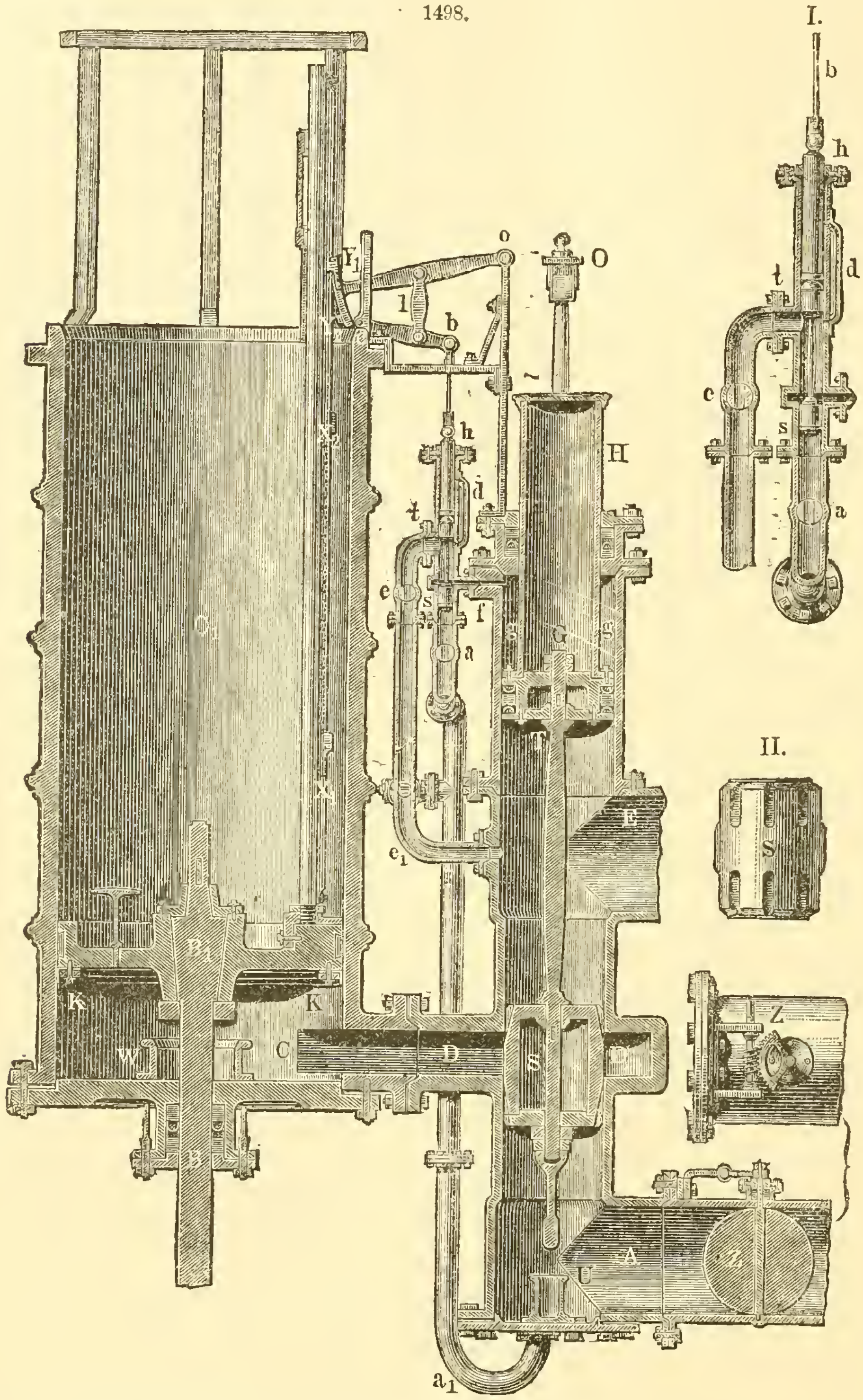
cylinder *G H* is added to the piston *T*; this hollow cylinder goes through the stuffing-box at *H*, and renders necessary the use of only enough water to fill the ring-shaped space *g*.

The alternate admission of the motive water to and shutting it off from the space *g* is effected by an auxiliary regulator, which is altogether similar to the main regulator, and like this consists of the regulator-piston *s*, the counter-piston *t*, and the thick piston-rod passing through the stuffing-box *h*. At the position *s t h*, shown in the figure, the motive water can pass unhindered through the passage *e f* into the space *g*; but if *s t h* is raised so that *s* stands over *f*, the connection is interrupted, and at the same time a passage $a\ a_1$ is opened, through which the water in *g g* may flow out as the piston *T* ascends. Finally, to connect the auxiliary regulator apparatus *s t h* with the working engine, a rod is affixed to the driving-piston $K\ K_1$; this rod moves in a guide above, and is furnished with a series of holes into which the tappets $X_1$ and $X_2$ may be placed on opposite sides of the rod. The rod *b h* is attached to two levers, movable about *c* and *o*, and connected with each other by the piece *l*; one of these levers ends in a circular piece which carries two knobs $Y_1$ and $Y_2$. Toward the end of the up stroke of the driving-piston, $X_1$ strikes $Y_1$, and *s t h* is thus carried to its highest position; toward the end of the down stroke, on the contrary, $X_2$ strikes the knob $Y_2$, and the rod *s t h* is carried back by the lever to its lowest position. The regulation of the machine is thus effected by *S T*, and the piston $K\ K_1$ ascends and descends with regularity.

Figs. 1499, 1500, and 1501 represent a water-pressure engine erected at the Alport mines in Derbyshire, England, in 1845. Fig. 1499 is a front elevation of the combined-cylinder engine; Fig.

1500 is a sectional view, and Fig. 1501 is a general plan. *Pc* is the bottom of the pressure column, 130 feet high and 24 inches internal diameter. *C C* are the combined cylinders, each 24 inches diameter, open at top, with hemp-packed pistons *a*, Fig. 1500, and piston-rods *m*, combined by a

1498.



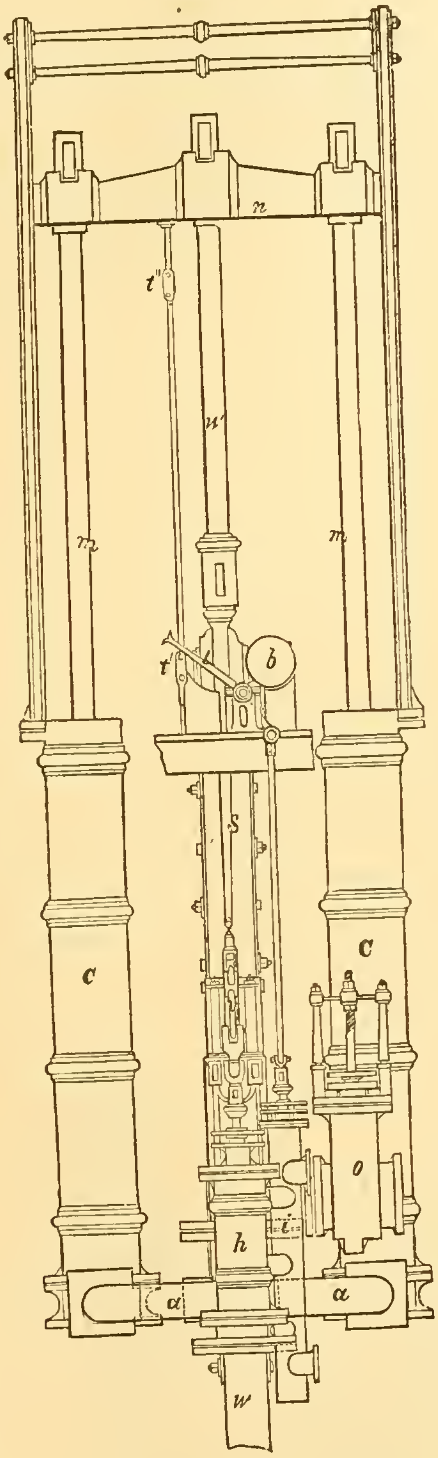

cross-head *n*, Fig. 1499, working between guides in a strong frame. The admission throttle-valve is a sluice-valve, shown at *o*, Fig. 1499, and between the letters *b* and *e* in Fig. 1501. The main or working valve is a piston *g*, 18 inches in diameter, Fig. 1500, with its counter or equilibrium piston above. The orifice for the admission of the pressure water is between the two pistons. The intermediate pipe *a* is a flat pipe, into which numerous apertures lead from the valve-cylinder, seen immediately under *g*, Fig. 1500. The valve-piston is in the position for discharging the water from the cylinders through the pipe *e*, Fig. 1501, by the sluice-valve *k*.

The valve-gear is worked by an auxiliary engine *h*, Fig. 1500, by means of the lever *v*. The auxiliary engine-valves are piston-valves in the valve-cylinder *i*, Figs. 1499 and 1500, communicating with the pressure-pipes by a small pipe, provided with cocks, as shown in Fig. 1501. The motion of the auxiliary engine-valves is effected by a pair of tappets *t' t''*, Fig. 1499, set on a vertical rod attached to the cross-head *n*. These tappets move the fall-bob *B* by means of the cantilever *t*, Fig. 1501, the other end of the lever being linked to the rod *s*, which again is linked to the auxiliary piston-valve rod.

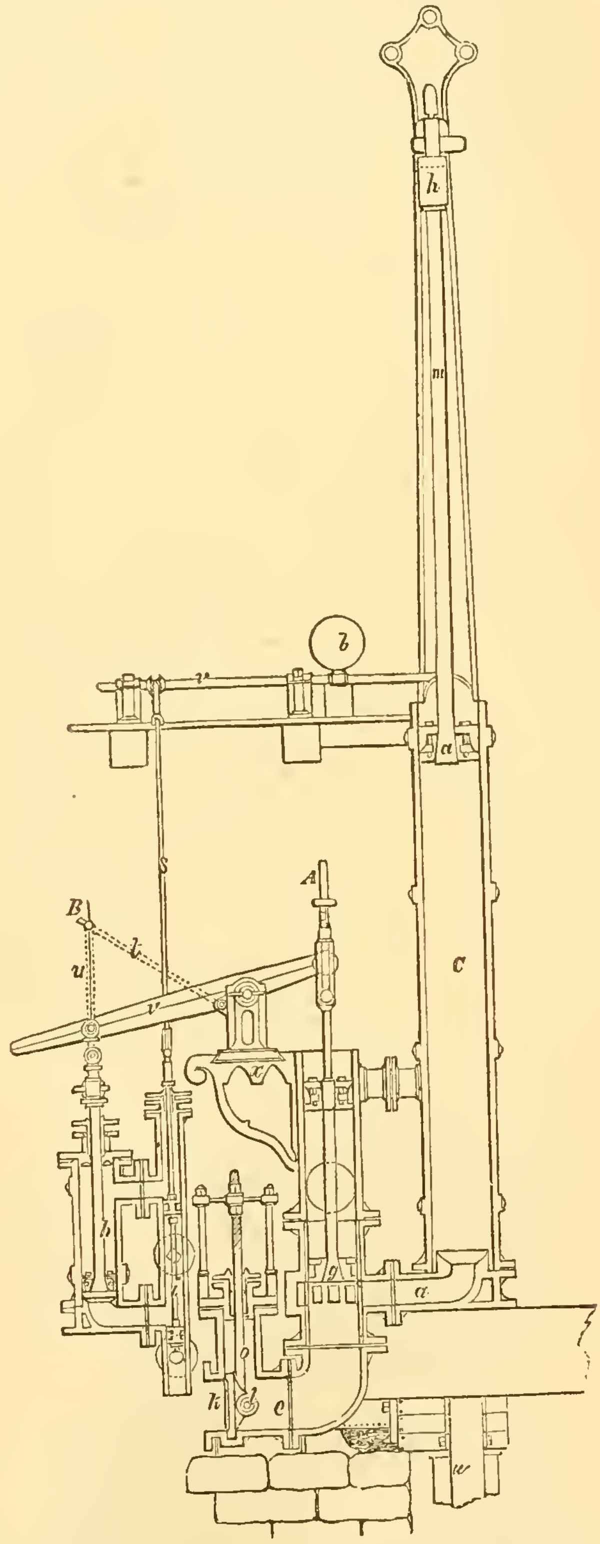
The play of the machine is now manifest. It is in every respect analogous to the Hartz and Huel-

goat engines, described by Weisbach. The average speed of the engine is 140 feet per minute, or 7 double strokes per minute. This requires a velocity of something less than $2\frac{1}{2}$ feet per second of the water in the pressure-pipes; and as all the valve apertures are large, the hydraulic resistances must be very small. The engine is direct-acting, drawing water from a depth of 135 feet, by means of the spear *w w*, Figs. 1501 and 1502. The "box" or *bucket* of the pump is 28 inches in diameter, so that the discharge is 266 gallons per stroke, or, when working full speed, 1,862 gallons per minute. The mechanical effect due to the fall and quantity of water consumed is nearly 140 horse-power. The mechanical effect involved in the discharge of the last-named quantity of water is

1500.




1501.



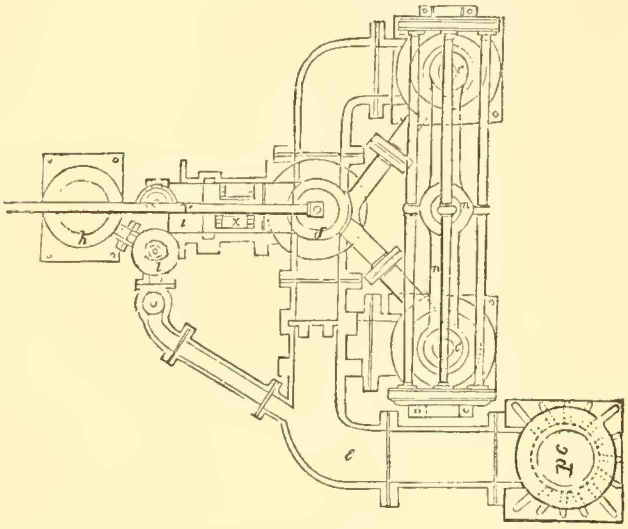

nearly 74 horse-power, so that, supposing the efficiency of the engine and pumps to be on a par with each other, the efficiency of the two being $\eta_1 = 71.15$, the efficiency of the engine alone $\eta =$

$$\frac{1 + \eta_1}{2} = \frac{1 + .71}{2} = .85.$$

*Efficiency of the foregoing Types of Engine.*—According to Weisbach, no exhaustive experiments have been made upon the performance of the water-pressure engines above described. They are

used generally only to raise water from mines by the aid of pumps; and the experiments that have been made bear only upon the apparatus of pumps and pressure engines as a whole. Full calculations as to the efficiency of the engines will, however, be found in the work already quoted. Comparing water-pressure engines with water-wheels, the same authority states that "water-wheels have the advantage of simplicity and cheapness; and on this account, where they can be used, or with a fall of about 60 feet an overshot wheel, or two overshot wheels where the fall is 100 feet, give better results than a water-pressure engine. If the fall, however, is more than the height of two of the largest wheels, a water-pressure engine is to be preferred to a system of wheels, the first cost and maintenance of which will probably be the greater. With great falls, however, horizontal water-wheels can also be used, and in point of simplicity and cheapness these have the advantage. But it is quite otherwise as regards the duty and efficiency of the machines. With great heads, the highest percentage attainable with a turbine or reaction wheel is 0.70, while water-pressure engines give a percentage of 0.80. Consequently, where with a great head it is necessary to utilize all the power, a water-pressure engine should be used; but where there is no lack of power and it is desired to economize the cost, the turbines have the advantage."

1502.



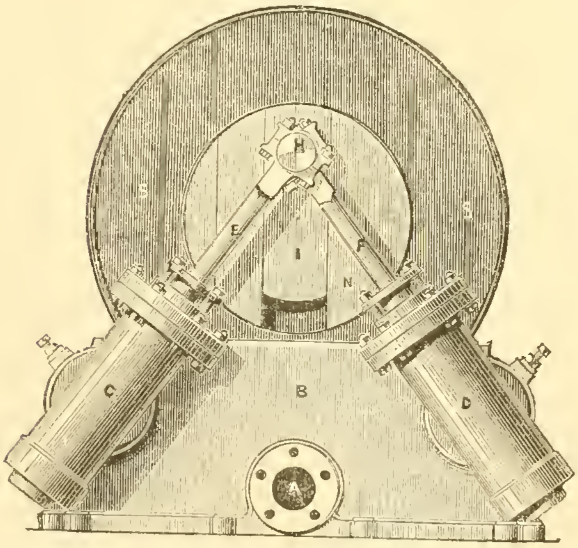
Full information with bibliographical references relative to the above-described forms of water-pressure engines will be found in Weisbach's "Manual of the Mechanics of Engineering and of the Construction of Machines," translated by Dubois, New York, 1878 (Vol. II., Section II.).

*Water-Pressure Engines as General Motors* are either reciprocating or rotary, and all quite simple in construction. In this country, in cities where such a use of the water-supply is permissible, they are frequently driven from the town mains. Various projects have from time to time been suggested for constructing water-towers where there are no regular water-works, and distributing from these water under pressure to afford power for small manufactories. Where power is taken from the regular mains, it is often found that the pressure varies, being always highest in the mornings and evenings, and lowest during the middle of the day when most required. An engineer has therefore to construct an engine of sufficient power to perform the requisite amount of work at the lowest usual pressure in the main; and thus at the period when the pressure is highest a greater power is exerted, and consequently a larger quantity of water is used than is necessary; for the cylinder must be completely filled with water at every stroke, whether the power is required or not. When these two disadvantages are taken into account, there is often a loss of water to the extent of from 60 to 70 per cent.

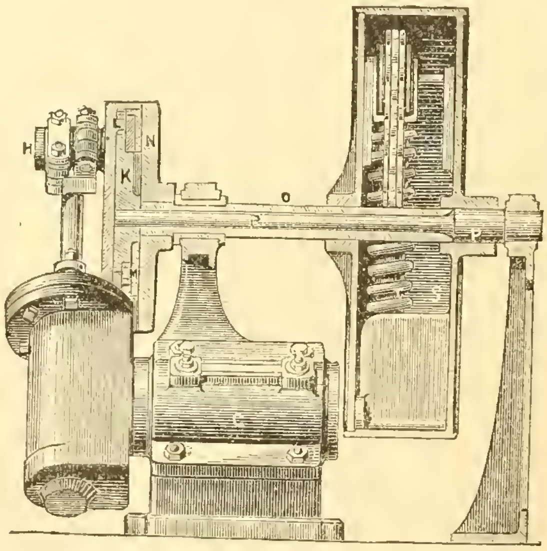
*The Hastie Economic Water-Pressure Engine.*—It is claimed that in this machine, the invention of Mr. John Hastie of Greenock, the above-mentioned difficulty has been obviated. We take the following description and illustrations from *Engineering*, xxvi., 371:

"Figs. 1503 to 1507 give details of a hydraulic engine (in this case with two cylinders) constructed

1503.



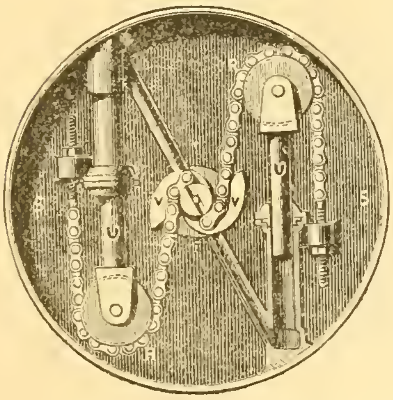
1504.



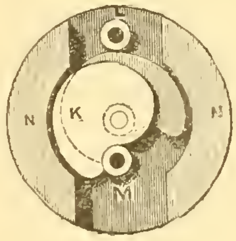
for the lower pressures, and the working of which will be understood from the following description: *A* is the inlet-pipe, which, by means of passages in the frame of engine *B*, conveys the water to the oscillating cylinders *C* and *D*; each of these is fitted with long trunnions *G*, which contain the admission-ports, and which during their oscillation act as valves; the outlet for the water is by

similar passages leading to a pipe in the opposite side of framing from *A*. The ends of the piston-rods *E* and *F* act direct on the crank-pin *H*; this pin is formed on a sliding frame *I*, which frame effects the necessary adjustment of stroke; it is formed in two pieces, an outer and an inner, bolted

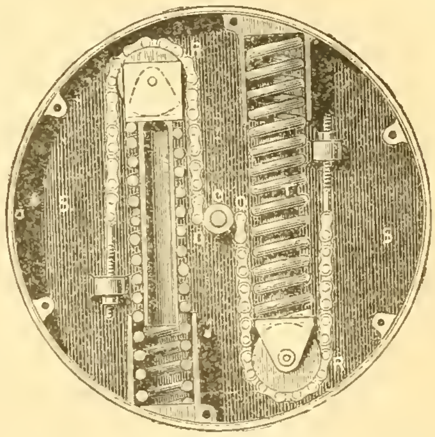
1504.



1505.

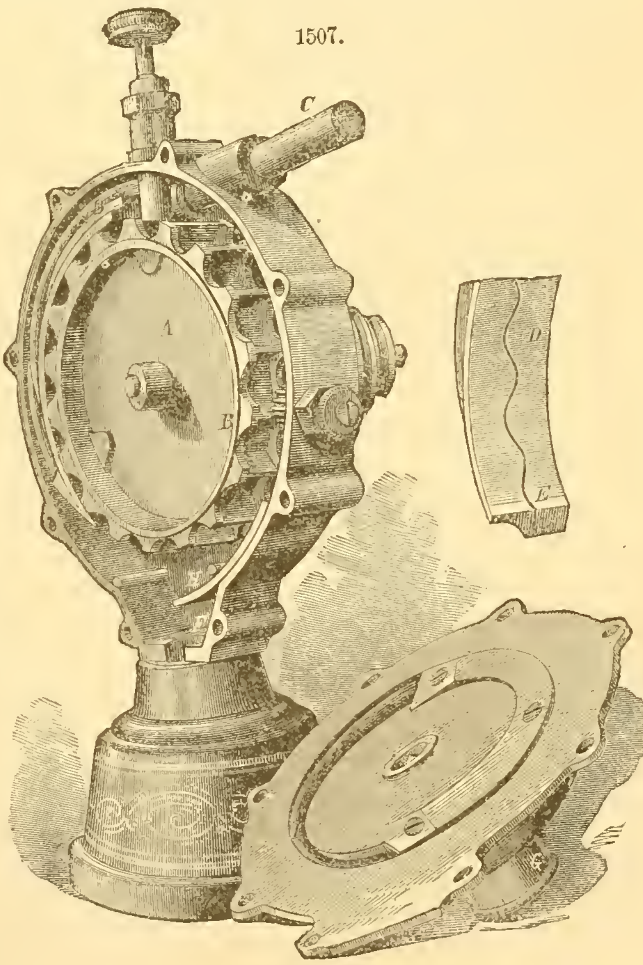


1506.



together at the ends, and between which is a space in which the double cam *K* works. The outer plate has a small steel roller *L* working on outer half of cam, and the inner plate a similar roller *M* working on inner half of cam. The disk *N* is keyed on the hollow shaft *O* and the cam *K* on shaft *P*, reduced to pass through centre of shaft *O*. This latter shaft *O* has two snugs formed on it, to which chains *R* are attached; the shaft *P* has the spring case *S* keyed on it, which contains the two springs *T*. The action of this part of the arrangement is as follows: When the engine is at rest the springs have just as much pressure on them as holds the roller against the inner part of the curve of cam; this pressure is also sufficient to prevent any change in position of the crank-pin should the engine be running without load; when the load is thrown on, the springs become compressed in proportion to the amount of load; the compression of the springs alters the relative positions of the shafts *O* and *P*, which causes the roller *L* to move along the curve of cam, at the same time shifting position of sliding frame *I*, and giving an increased stroke in proportion to the work being done. On the weight being removed the pressure on the springs causes the roller *M* working on the cam to bring the frame and crank-pin back to the inner position, and through this automatic variation of the stroke the water required is in proportion to the work done. When a very high pressure of water is employed, such as is obtained with the accumulator, the springs are dispensed with, and an arrangement shown in Fig. 1504 is employed. In this arrangement two water-rams *U* occupy the place of the springs; these are connected through centre of shaft *P* with the supply-pipe, and are therefore under the same pressure as is employed to work the engine. The chains *R* are employed in a similar manner as in connection with the springs, but, instead of being wound directly on the body of shaft *O*, they are wound on cams *V*; in this way increased power is required to force back the rams in proportion to the distance from the centre of shaft at which the chain *R* acts, and the effect is identical with that obtained from the springs."

1507.

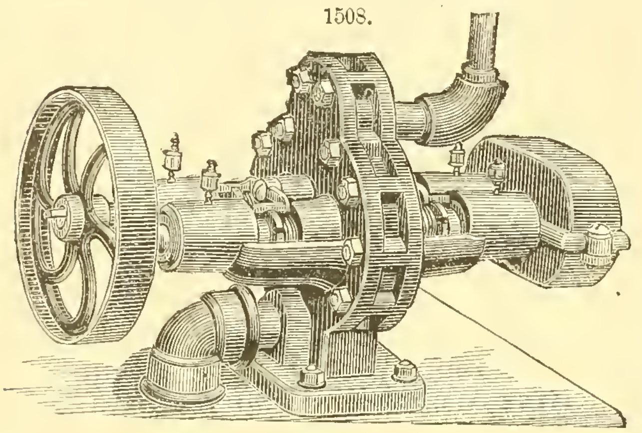


The following data have been derived from experiments with this engine, the lift being 22 feet:

| Weight lifted, Lbs. | Average Water used each Lift, Gallons. | Weight lifted, Lbs. | Average Water used each Lift, Gallons. |
|---|---|---|---|
| 382 | 10 | 867 | 20 |
| 567 | 14 | 967 | 21 |
| 667 | 16 | 1,067 | 22 |
| 767 | 17 | | |

*Rotary Water-Pressure Engine.*—An example of the rotary form of water-pressure engine, a type used to considerable extent in this country for running light elevators, lathes, printing-presses, blowers, sewing-machines, organs, coffee-roasters, spinning-mills, sausage-mills, etc., etc., or for use in hotels, laundries, forges, etc., is represented in Fig. 1507, and is the invention of Mr. James Talley, Jr., of Missouri. The buckets on the wheel *A* are set sloping at an angle of about 30° with the radial lines of the wheel, and between each pair the flanges are scalloped out, as shown. On the face of the wheel are formed annular flanges *B*, which bear against the inner faces of the casing, preventing side play of the water. The wheel is placed eccentrically in the casing so as to touch or nearly touch the latter on the inlet side, and to leave a large waterway on the outlet side. The induction-pipe *C* terminates on the inner face of the casing in a wave-line chute *D*. The width of this aperture is greatest at *E*, where the stream is first discharged upon the wheel, and from that point it gradually diminishes as shown, having the greatest weight of water at *E*, at the other (on the blow-pipe principle) the greatest force. The distance over which this diminution takes place may be varied so as to deliver the water upon one or more buckets of the wheel. Two outlets are provided for the escape of the spent water. The first of these, at *F*, is used to discharge the water from the casing at the bottom when the machine is used in a vertical position. The other is formed on the side which becomes the bottom when the machine is placed horizontally or in turbine position. A screw-cap *G* is placed upon either outlet when not in use. A slide or gate *H* is arranged in the casing so as to close the orifice *F* when not in use. By the wave-line chute it is claimed that the water is given in one continuous sheet and not by periodical jets. The working side of the wheel thus becomes a lever, and there is no waste until the outlet is reached. A tapering duct *I* is formed on the side piece, and gradually widens to a point diametrically opposite that where the width of said duct is about equal to the diameter of the orifice *G*. From the large end of this duct there is a passage to the discharge outlet, which passage is so formed as to relieve the wheel from back pressure of spent water. It is stated that a 5-inch wheel of this type, with 70 lbs. pressure of water and less than three-sixteenths of an inch inlet, has driven a half-horse power 14-inch metal-turning lathe.

1508.



*Root's Hydraulic Engine*, represented in Fig. 1508, is constructed on the principle of the Root blower (see Blowers), and has proved advantageous for furnishing light power, especially for operating the bellows of large organs.

*Table showing Dimensions, Power, etc., of Root's Hydraulic Engine.*

| DETAILS. | No. 1. | No. 3. | No. 4. | No. 7. | No. 10. | No. 11. | No. 12. |
|---|---|---|---|---|---|---|---|
| Diameter of gears, inches | 2½ | 2½ | 3½ | 5 | 6½ | 6½ | 6½ |
| Face of piston, inches | 1½ | 2½ | 1½ | 1½ | 2 | 4 | 6 |
| Diameter of supply-pipe, inches | 1 | 1¼ | 1¼ | 2 | 2½ | 3 | 3½ |
| " of discharge-pipe, inches | 1¼ | 1½ | 1½ | 2½ | 3 | 3½ | 4 |
| Length of engine, inches | 12 | 13 | 22¼ | 26½ | 38½ | 40½ | 42½ |
| Width of engine, inches | 8 | 8 | 11 | 15½ | 20 | 20 | 20 |
| Height of engine, inches | 8 | 8 | 13 | 16½ | 22½ | 22½ | 22½ |
| Cubic inches of water per revolution | 12.7 | 21.2 | 34.6 | 69.6 | 159.2 | 318.3 | 477.8 |
| Revolutions per minute | 250 | 200 | 180 | 150 | 120 | 100 | 85 |
| Horse-power at 60 lbs. per square inch | 0.25 | 0.45 | 0.5 | 1.1 | 2.5 | 3.5 | 4.5 |

ENGRAVING.—Engraving on Copper is performed by cutting lines representing the subject on a copper plate by means of a steel instrument ending in an unequal-sided pyramidal point, such instrument being called a graver or burin, without the use of aquafortis. Besides the graver there are other instruments used in the process, viz.: a scraper, a burnisher, an oil-stone, and a cushion for supporting the plate. In cutting the lines on the copper the graver is pushed forward in the direction required, being held in the hand at a small inclination to the plane of the copper. The use of the burnisher is to soften down lines that are cut too deep, and for burnishing out scratches in the copper; it is about 3 inches long. The scraper, like the last, is of steel, with three sharp edges to it, and about 6 inches long, tapering toward the end. Its use is to scrape off the burr raised by the action of the graver. To show the appearance of the work during its progress, and to polish off the burr, engravers use a roll of woolen or felt called a rubber, which is put in action with a little olive-oil. The cushion, which is a leather bag about 9 inches in diameter filled with sand, for laying the plate on, is now rarely used except by writing-engravers. For architectural subjects, or in skies, where a series of parallel lines are wanted, a ruling-machine is used; the accuracy of its operation is exceedingly perfect. This is made to act on an etching ground by a point or knife connected with the apparatus, and bit in with aquafortis in the ordinary way.

The plate of copper must be perfectly polished, very level, and free from every imperfection; to this must be transferred an exact copy of the outlines of the drawing. To do this, the plate is heated in an oven or otherwise, very uniformly, till it is sufficiently hot to melt white wax, a piece of which is then rubbed over it and allowed to spread so as to form a thin coat over the whole surface, after which

it is left in a horizontal position till the wax and plate are cold. A tracing being taken of the original design with a black-lead pencil on a piece of thin tracing-paper, this is spread over the face of the prepared plate with the lead lines downward, and, being secured from slipping, a strong pressure is made use of by a press or otherwise, by which operation the lead lines are nearly obliterated on the paper, being transferred to the white wax on the plate. These pencil marks on the wax are now traced with a fine steel point, so as just to touch the copper; the wax being then melted off, a perfect outline will be found on the copper; and on this the engraver proceeds to execute and finish his work. With respect to the process itself it would be useless to speak; it depends on manual dexterity and genius, which it is impossible to teach by description.

Engraving on Steel.—The method of engraving is the same as copperplate engraving, except in certain modifications in the use of the acids, and therefore, so far as the process is concerned, no particular description is necessary; but it will be proper to explain the means employed for decarbonizing the steel plate so as to reduce it to a proper state for being acted upon by the graving-tool. Mr. Perkins, an eminent artist and engineer (a native of Massachusetts), has the merit of having established engraving on steel. About the year 1823 he was induced to visit London, where he obtained a patent for the invention; this was intended principally to prevent the forgery of bank-notes, which at that time, or rather previously to that time, had been carried on to a very fearful extent. The method employed for decarbonizing and recarbonizing the plate may be applicable to many other useful purposes, and we shall therefore give it in the words of the patentee. "In order to decarbonate the surfaces of cast-steel plates, cylinders, or dies, by which they are rendered much softer and fitter for receiving either transferred or engraved designs, I use pure iron filings divested of all foreign or extraneous matters. The stratum of decarbonated steel should not be too thick for transferring fine and delicate engravings—for instance, not more than three times the depth of the engraving; but for other purposes the surface of the steel may be decarbonated to any required thickness. To decarbonate it to a proper thickness for a fine engraving, it is to be exposed for 4 hours in a white heat, inclosed in a cast-iron box with a well-closed lid. The sides of the box are made at least three-quarters of an inch in thickness, and at least a thickness of half an inch of pure iron filings should cover or surround the cast-steel surface to be decarbonated. The box is allowed to cool very slowly, which may be effected by shutting off all access of air to the furnace, and covering it with a layer of 6 or 7 inches in thickness of fine cinders. Each side of the steel plate, cylinder, or die must be equally decarbonated, to prevent it from springing or warping in hardening. It is also found that the safest way to heat the plates, cylinders, or dies is by placing them in a vertical position. The best steel is preferred to any other sort of steel for the purpose of making plates, etc., and more especially when such plates, etc., are intended to be decarbonated. The steel is decarbonated solely for the purpose of rendering it sufficiently soft for receiving any impression intended to be made thereon; it is therefore necessary that after any piece of steel has been so decarbonated, whether it be in the shape of a plate, a cylinder, or a die, it should, previously to being printed from, be again carbonated or reconverted into steel capable of being hardened. In order, therefore, to effect this recarbonization or reconversion into steel, the following process is employed: A suitable quantity of leather is to be converted into charcoal by the well-known method of exposing it to a red heat in an iron retort for a sufficient length of time, or until most of the evaporable matter is driven off the leather. Having thus prepared the charcoal, it is reduced to a very fine powder; then take a box made of cast-iron, of sufficient dimensions to receive the plate, cylinder, or die which is to be reconverted into steel, so as that the intermediate space between the sides of the said box and the plate or die may be about an inch. This box is to be filled with the powdered charcoal, and, having covered it with a well-fitted lid, let it be placed in a furnace similar to those used for melting brass, when the heat must be gradually increased until the box is somewhat above a red heat; it must be allowed to remain in that state till all the evaporable matter is driven off from the charcoal; then remove the lid from the box, and immerse the plate, cylinder, or die into the powdered charcoal, taking care to place it as nearly in the middle as possible, so that it may be surrounded on all sides by a stratum of the powder of nearly a uniform thickness. The lid being replaced, the box, with the plate, cylinder, or die, must remain in the degree of heat before described for from 3 to 4 hours, according to the thickness of the body so exposed; 3 hours are sufficient for a plate of half an inch in thickness, and 5 hours when the steel is one and a half inch in thickness. After the plate or other piece of steel has been thus exposed to the fire for a sufficient length of time, take it from the box and immediately plunge it into cold water. Here it is important to observe, that it is found by experience that the plates or other pieces of steel, when plunged in cold water, are least liable to be warped or bent when they are held in a vertical position, or made to enter the water in the direction of their length. If a piece of steel, heated to a proper degree for hardening, be plunged into water and suffered to remain there until it becomes cold, it is found by experience to be very liable to crack or break, and in many cases it would be found too hard for the operations it was intended to perform.

"If the steel cracks or breaks, it is spoiled. In order, therefore, to fit it for use, should it happen not to be broken in hardening, it is the common practice to heat the steel again, in order to reduce or lower its temper, as it is technically called. The degree of heat to which it is now exposed determines the future degree of hardness, or the temper, and this is indicated by a change of color upon the surface of the steel. During this heating a succession of shades is produced, from a very pale straw color to a very deep blue. It is found, however, by long experience, that on plunging the steel into cold water and allowing it to remain there no longer than is sufficient for lowering the temperature of the steel to the same degree as that to which a hard piece of steel must have been raised to temper it in the common way, it not only produces the same degree of hardness in the steel, but, what is of much more importance, almost entirely does away the risk or liability of its cracking or breaking. It is impossible to communicate by words, or to describe, the criterion by which we can

determine when the steel has arrived at the proper degree of temperature after being plunged into cold water; it can only be learned by actual observation, as the workman must be guided entirely by the kind of hissing or singing noise which the heated steel produces in the water while cooling. From the moment of its first being plunged into the water the varying sound will be observed; and it is at a certain tone, before the noise ceases, that the effect to be produced is known.

"The only directions which can be given whereby the experimentalist can be benefited are as follows, namely: To take a piece of steel which has already been hardened by remaining in the water till cold, and by the common method of again heating it to let it be brought to the pale yellow or straw color which indicates the desired temper of the steel plate to be hardened. By the above process, as soon as he discovers this color to be produced, to dip the steel into water and attend carefully to the hissing, or as some call it a singing, which it occasions, he will then be better able, and with fewer experiments, to judge of the precise time at which the steel should be taken out. It is not meant to be understood that the temper indicated by a straw color is that to which the steel plate, cylinder, or die should be ultimately reduced, because it would then be found too hard, but merely that the temperature which would produce that color is that by which the peculiar sound would be occasioned, when the steel should be withdrawn from the water for the first time. Immediately on withdrawing it from the water, the steel plate, cylinder, or die must be laid upon or held over the fire, and heated uniformly until its temperature is raised to that degree at which tallow would be decomposed; or, in other words, until a smoke is perceived to arise from the surface of the steel plate, after having been rubbed with tallow: now the steel plate must be again plunged into water, and kept there until the sound becomes somewhat weaker than before. It is then to be taken out and heated a second time to the same degree, by the same rule of smoking tallow as before, and the third time plunged into water, till the sound becomes again weaker than the last; exposed the third time to the fire as before; and for the last time returned into the water and cooled. After it is cooled, clean the surface of the steel plate, cylinder, or die, by heating it over the fire. The temper must be finally reduced by bringing on a brown or such other lighter or darker shade of color as may best suit the quality of the steel for the purpose to which it is to be applied."

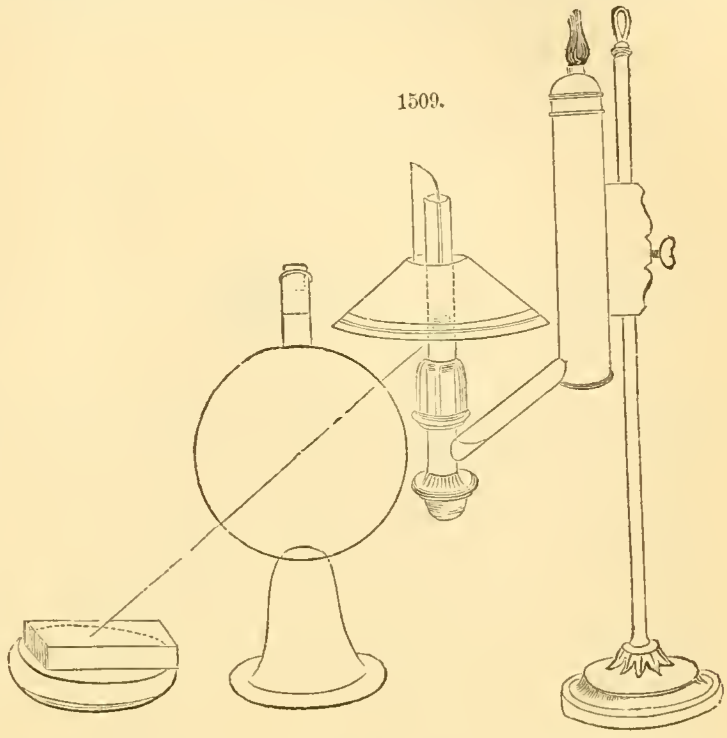
The following is another improvement of Mr. Perkins: A cylinder of very soft or decarbonized steel is made to roll, under a great pressure, backward and forward on the hardened engraved plate, till the entire impression from the engraving is seen on the cylinder in alto-rilievo. The cylinder is then hardened and made to roll again backward and forward on a copper or soft steel plate, whereby a perfect facsimile of the original is produced of equal sharpness. The improved press now generally used by steel and copperplate printers is also due to Mr. Perkins. In short, he bears the same relation to steel engraving that Senefelder does to the lithographic process. A description of the method of engraving U. S. Treasury notes, etc., on steel, will be found in the *Scientific American*, xxvii., 208.

Engraving on Silver and Gold.—M. Poitevin has succeeded in producing plates, engraved either in relief or in sunk lines, from which proofs may be taken. For the carrying out of this process, from two to three hours only are required. The engraving is first exposed to the vapor of iodine, which becomes deposited upon the black parts only. The iodized engraving is then applied, with slight pressure, to a plate of silver, or silvered copper, polished in the same manner as daguerreotype plates. The black parts of the engraving, which have taken up the iodine, part with it to the silver, which is converted into an iodide at those parts opposite to the black parts of the design. The plate is then put in communication with the negative pole of a small battery, and immersed in a saturated solution of sulphate of copper, connected with the positive pole by means of a rod of platinum. The copper will be deposited only on the non-iodized parts, corresponding to the white parts of the engraving, of which a perfect representation will thus be obtained—the copper representing the white parts, and the iodized silver the black parts. The plate must be allowed to remain in the bath for a very short time only; for, if left too long, the whole plate would become covered with copper. The plate, after having received the deposit of copper, must be carefully washed, and afterward immersed in a solution of hyposulphite of soda, to dissolve the iodide of silver, which represents the black parts; it is then well washed in distilled water, and dried. The next operation is to heat a plate to a temperature sufficient to oxidize the surface of the copper, which successively assumes different tints, the heating being stopped when a dark-brown color is obtained. It is then allowed to cool, and the exposed silver is amalgamated—the plate being slightly heated, to facilitate the operation. As the mercury will not combine with the oxide of copper, a design is produced, of which the amalgamated parts represent the black, and the parts of the plate covered with oxide of copper represent the white parts. The amalgamation being complete, the plate is to be covered with three or four thicknesses of gold leaf; and the mercury is evaporated by heat, the gold only adhering to the black parts. The superfluous gold must then be cleaned off with the scratch-brush; after which the oxide of copper is dissolved by a solution of nitrate of silver, and the silver and copper underneath are attacked with dilute nitric acid. Those parts of the design which are protected by the gold, not being attacked, correspond to the black parts of the plate; the other parts, corresponding to the white parts of the engraving, may be sunk to any required depth. When this operation is completed the plate is finished, and may be printed from in the ordinary method of printing from woodcuts.

To obtain from the same prints plates with sunk lines similar to the ordinary engraved copper plates, a plate of copper covered with gold is operated upon. On immersion in the sulphate-of-copper solution the parts corresponding to the white parts will become covered with copper. The iodine, or compound of iodine, formed, is then to be removed by the hyposulphite, the layer of deposited copper is oxidized, and the gold amalgamated, which may be removed by means of nitric acid, the oxide of copper being dissolved at the same time. In this instance the original surface of the plate corresponds to the white parts of the print, and the sunk or engraved parts to the black parts, as in the ordinary copperplate engravings.

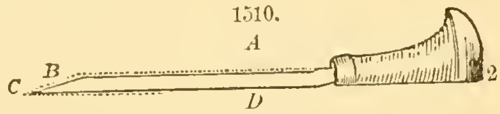
Engraving on Wood.—There are various modes for protecting the eyes when working by lamp-light, but we are aware of only one which both protects the eyes from the light and the face from the heat of the lamp. This consists in filling a large transparent glass globe with clear water, and placing it in such a manner between the lamp and the workman that the light, after passing through the globe, may fall directly on the block, in the manner represented in Fig. 1509. The height of the lamp can be regulated according to the engraver's convenience, in consequence of its being movable on the upright piece of iron or other metal which forms its support. The dotted line shows the direction of the light when the lamp is elevated to the height here seen; by lowering the lamp a little more, the dotted line would incline more to a horizontal direction, and enable the engraver to sit at a greater distance. By the use of these globes one lamp will suffice for three or four persons, and each person have a clearer and cooler light than if he had a lamp without a globe solely to himself.

1509.



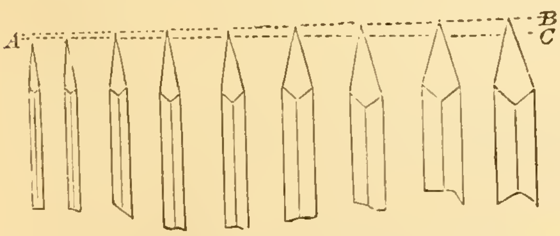
There are only four kinds of cutting tools* necessary in wood-engraving, namely: gravers, tint tools, gouges or scoopers, and flat tools or chisels. Of each of these four kinds there are various sizes. Fig. 1510 shows the form of a graver that is principally used for outlining or separating one figure from another. *A* is the back of the tool, *B* the face, *C* the point, and *D* what is technically called the belly. The horizontal dotted line *C* 2 shows the surface of the block, and the manner in which part of the handle is cut off after the blade is inserted.† This tool is very fine at the point, as the line which it cuts ought to be so fine as not to be distinctly perceptible when the cut is printed, as the intention is merely to form a termination or boundary to a series of lines running in another direction. Though it is necessary that the point should be very fine, yet the blade ought not to be too thin, for then, instead of cutting out a piece of the wood, the tool will merely make a delicate opening, which would be likely to close as soon as the block should be exposed to the action of the press. When the outline tool becomes too thin at the point, the lower part should be rubbed on a hone, in order to reduce the extreme fineness.

1510.

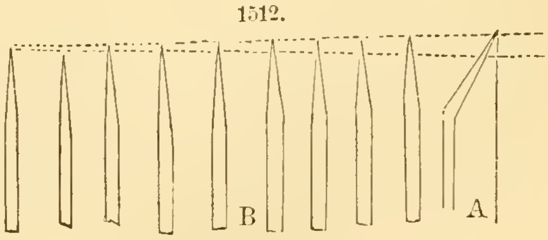



About 8 or 9 gravers of different sizes, beginning from the outline tool, are generally sufficient. The blades differ little in shape, when first made, from those used by copperplate engravers; but in order to render them fit for the purpose of wood-engraving, it is necessary to give the points their peculiar form by rubbing them on a Turkey stone. In Fig. 1511 are shown the faces and part of the backs of nine gravers of different sizes. The lower dotted line *A C* shows the extent to which

1511.




1512.




the points of such tools are sometimes ground down by the engraver in order to render them broader. When thus ground down the points are slightly rounded, and do not remain straight as if cut off by the dotted line *A C*. These tools are used for nearly all kinds of work, except for series of parallel lines, technically called "tints." The width of the line cut out, according to the thickness of the graver toward the point, is regulated by the pressure of the engraver's hand.

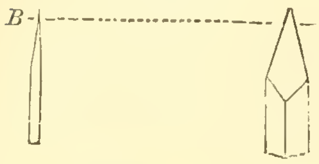
Tint tools are chiefly used to cut parallel lines forming an even and uniform *tint*, such as is usually seen in the representation of a clear sky in woodcuts. They are thinner at the back but deeper

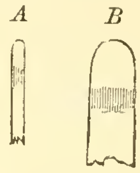
* A sharp-edged scraper, in shape something like a copperplate engraver's burnisher, is used in the process of *lowering*.

† The handle, when received from the turner's, is perfectly circular at the rounded end; but after the blade is inserted, a segment is cut off at the lower part, as seen in Fig. 1510.

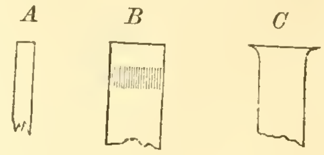
at the side than gravers, and the angle of the face, at the point, is much more acute. About 7 or 8, of different degrees of fineness, are generally sufficient. Fig. 1512 will afford an idea of the shape of the blades toward the point. The handle of the tint tool is of the same form as that of a graver. The figure marked *A* presents a side view of the blade; the others, marked *B*, show the faces. Some engravers never use a tint tool, but cut all their lines with a graver. There is, however, great uncer-

1513.




1516.




1514.

1515.

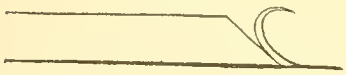
1517.

tainty in cutting a series of parallel lines in this manner, as the least inclination of the hand to one side will cause the graver to increase the width of the white line cut out, and undercut the raised one left, more than if in the same circumstances a tint tool were used. This will be rendered more evident by a comparison of the points and faces of the two different tools, Fig. 1513.

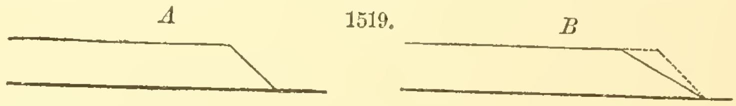
The tint tool, being very little thicker at *B* than at the point *A*, will cause a very trifling difference in the width of a line in the event of a wrong inclination, when compared with the inequality occasioned by the unsteady direction of a graver, whose angle at the point is much greater than that of a proper tint tool. Tint tools ought to be sufficiently strong at the back to prevent their bending in the middle of the blade when used; for with a weak tool of this kind the engraver cannot properly guide the point, and hence freedom of execution is lost. Tint tools that are rather thick in the back are to be preferred to such as are thin, not only from their allowing of great steadiness in cutting, but from their leaving the raised lines thicker at the bottom, and consequently more capable of sustaining the action of the press. A tint tool that is of the same thickness both at the back and the lower part, cuts out the lines in such a manner that a section of them appears as in Fig. 1514, the black raised lines from which the impression is obtained being no thicker at their base than at the surface; while a section of the lines cut by a tool that is thicker at the back than at the lower part appears as in Fig. 1515. It is evident that lines of this kind, having a better support at the base, are much less liable than the former to be broken in printing.

Gouges of different sizes, Fig. 1516, from *A* the smallest to *B* the largest, as here represented, are used for scooping out the wood toward the centre of the block; while flat tools or chisels, of

1518.



1519.




various sizes, are chiefly employed in cutting away the wood toward the edges. Flat tools of the shape seen at *C* are sometimes offered for sale by tool-makers, but they ought never to be used; for the projecting corners are very apt to cut under a line, and thus remove it entirely, causing great trouble to replace it by inserting new pieces of wood.

The face of both gravers and tint tools ought to be kept rather long than short; though if the point be ground too fine, it will be very liable to break. When, as in Fig. 1517, the face is long—or, strictly speaking, when the angle formed by the plane of the face and the lower line of the blade is comparatively acute—a line is cut with much greater clearance than when the face is comparatively obtuse, and the small shaving cut out turns gently over toward the hand. When, however, the face of the tool approaches to the shape seen in Fig. 1518, the reverse happens: the small shaving is rather ploughed out than cleanly cut out; and the force necessary to push the tool forward frequently causes small pieces to fly out at each side of the hollowed line, more especially if the wood be dry. The shaving also, instead of turning aside over the face of the rod, turns over before the point, as in Fig. 1518, and hinders the engraver from seeing that part of the penciled line which is directly under it. A short-faced tool of itself prevents the engraver from distinctly seeing the point. When the face of a tool has become obtuse, it ought to be ground to a proper form; for instance, from the shape *A* to that of *B*, Fig. 1519.

Gravers and tint tools when first received from the maker are generally too hard—a defect which is soon discovered by the point breaking off short as soon as it enters the wood. To remedy this,

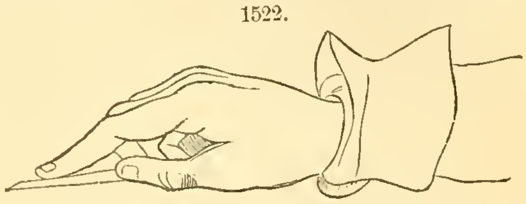
1520.

1521.

the blade of the tool ought to be placed with its flat side above a piece of iron—a poker will do very well—nearly red-hot. Directly it changes to a straw-color it is to be taken off the iron, and either dipped in sweet oil or allowed to cool gradually. If removed from the iron while it is still of a straw-color, it will have been softened no more than sufficient; but should it have acquired a purple tinge, it will have been softened too much, and, instead of breaking at the point as before, it will bend.

A small grindstone is of great service in grinding down the faces of tools that have become obtuse. A Turkey stone, though the operation requires more time, is however a very good substitute, as, besides reducing the face, the tool receives the point at the same time. Though some engravers use only a Turkey stone for sharpening their tools, yet a hone in addition is of great advantage. A graver that has received a final polish on a hone cuts a clearer line than one which has only been sharpened on a Turkey stone; it also cuts more pleasantly, gliding smoothly through the wood, if it be of good quality, without stirring a particle on each side of the line.

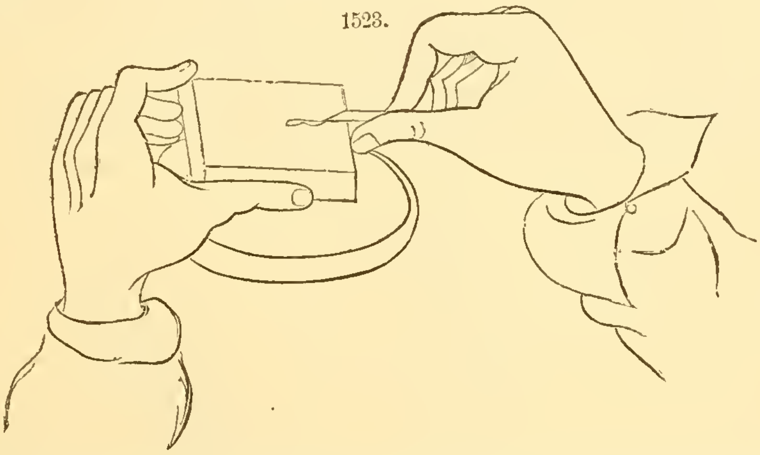
1522.



The gravers and tint tools used for engraving on a plane surface are straight at the point, as are here represented, Figs. 1520 and 1521; but for engraving on a block rendered concave in certain points by lowering, it is necessary that the point should have a slight inclination upward, as in Fig. 1520. The dotted lines show the direction of the point used for plane-surface engraving. There is no difficulty in getting a tool to descend on one side of a part hollowed out or lowered; but unless the point be slightly inclined upward, as is here shown, it is extremely difficult to make it ascend on the side opposite, without getting *too much hold*, and thus producing a wider white line than was intended.

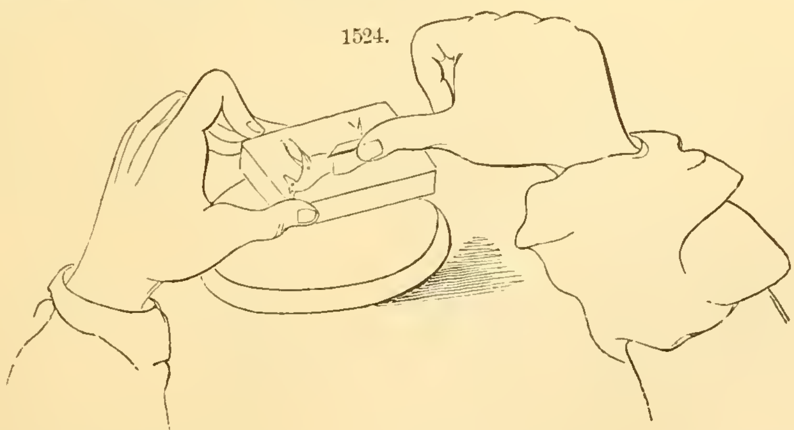
As the proper manner of holding the graver is one of the first things that a young wood-engraver is taught, it is necessary to say a few words on the subject. Engravers on copper and steel, who

1523.



have much harder substances than wood to cut, hold the graver with the forefinger extended on the blade beyond the thumb, Fig. 1522, so that by its pressure the point may be pressed into the plate. As box-wood, however, is much softer than copper or steel, and as it is seldom of perfectly equal hardness throughout, it is necessary to hold the graver in a different manner, and employ the thumb at once as a stay or rest for the blade, and as a check upon the force exerted by the palm of the hand, the motion being chiefly directed by the forefinger, as is shown in Fig. 1523. The thumb, with the end resting against the side of the block, in the manner represented, allows the blade to

1524.



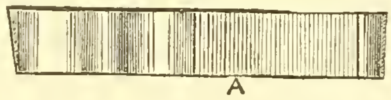
move back and forward with a slight degree of pressure against it, and in case of a slip it is ever ready to check the graver's progress. This mode of resting the thumb against the edge of the block is, however, only applicable when the cuts are so small as to allow of the graver, when thus guided and controlled, to reach every part of the subject. When the cut is too large to admit of this, the thumb then rests upon the surface of the block, as seen in Fig. 1524, still forming a stay to the blade of the graver, and a check to its slip, as before.

ENVELOPE MACHINERY. In the earliest stages of the invention, the paper blanks were cut out, and the subsequent folding performed, entirely by hand; but the necessity of a prodigious increase in the power of production speedily led to the employment of mechanical means for the entire manufacture. One of the first of these improvements was an improved paper-cutting machine,

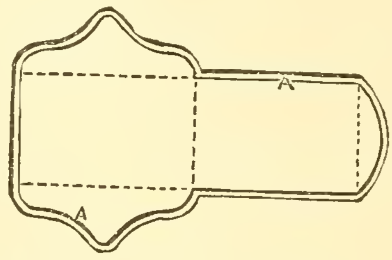
a plan for cutting out the blanks. Many envelope-makers use this machine now; but others employ a hollow cutting-die, cutting through about 250 sheets of paper at once.

Fig. 1525 is a sectional elevation of the die, and Fig. 1526 a plan. It is simply a knife shaped to the contour of the envelope blank, *A* being the sharp edge. This is forced through a thick pile of sheets by a convenient press, so as to produce blanks agreeing in shape to the interior of the two lines in Fig. 1526. This shape, it will be observed, is not one now in common use, but it serves as an example of some of the attempts which have been made to give additional security, and probably a greater appearance of style. The cut pieces are gummed on one side, at the ends of each flap; and when folded, as indicated by the dotted lines in the plan of the cutter, the long narrow part adheres

1525.




1526.

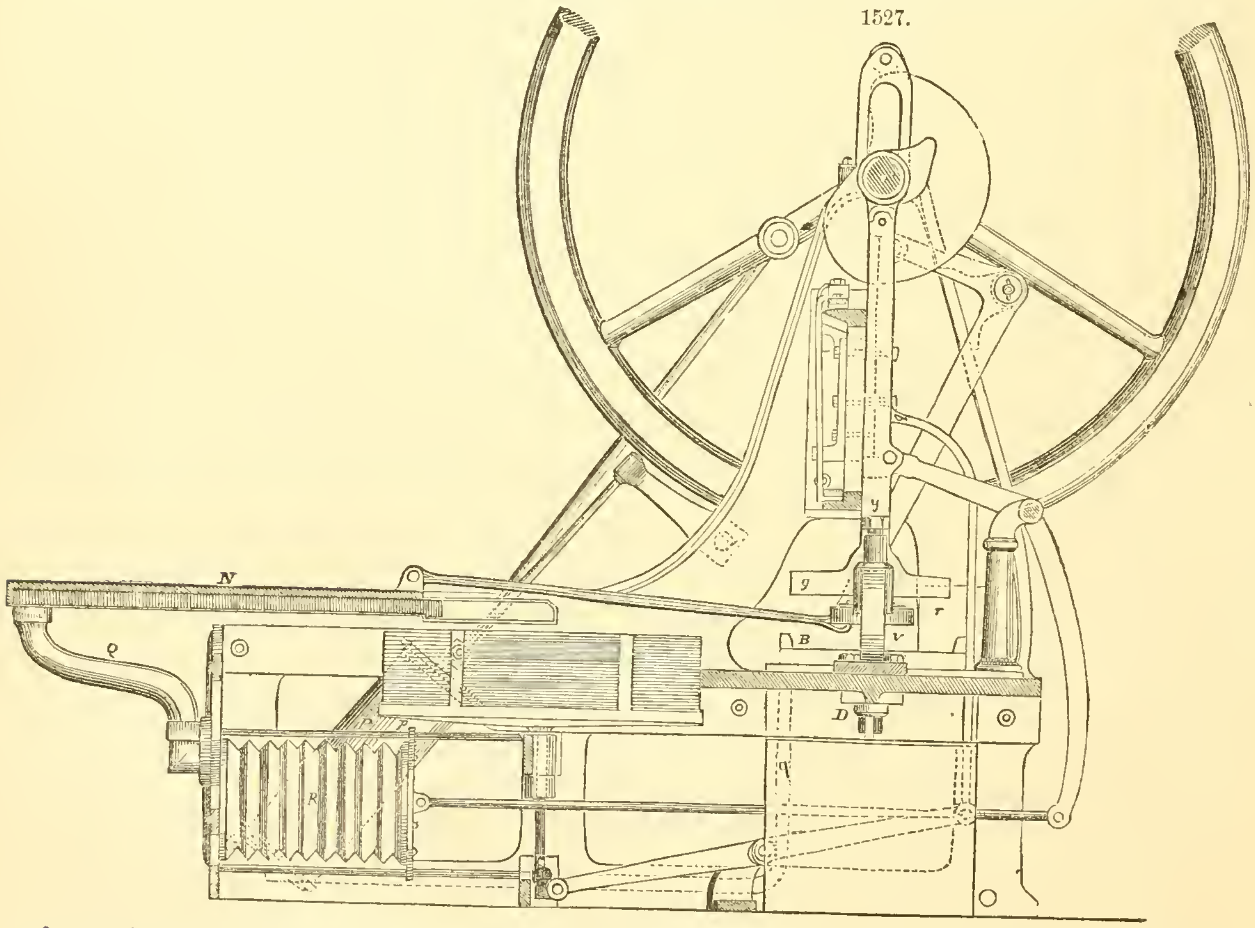



to one end of its counterpart, forming the back, and the remaining pair of flaps fold down upon it. This shape of envelope has, for many reasons, never come into ordinary use.

Figs. 1527, 1528, and 1529 exhibit, in elevation and detail, an improved folding-machine, patented in France by M. Rémond. In this machine some ingenious appliances are introduced, whereby atmospheric pressure is employed to facilitate the feeding in of the blanks to the folding apparatus, and the secondary folding action of the flaps in connection with the creasing plunger.

Fig. 1527 is a side elevation of the machine, partially in section. Fig. 1528 is a vertical section

1527.




of a portion of the machinery, taken at the dotted line *A B* in Fig. 1527. Fig. 1529 is a horizontal view or plan of the folding-table, with the details of the apparatus for receiving the blanks preparatory to folding. Fig. 1530 is a transverse section, taken at the dotted line *C D* in Fig. 1527. Fig. 1531 is a plan of the feeding-slide *N* in Fig. 1527.

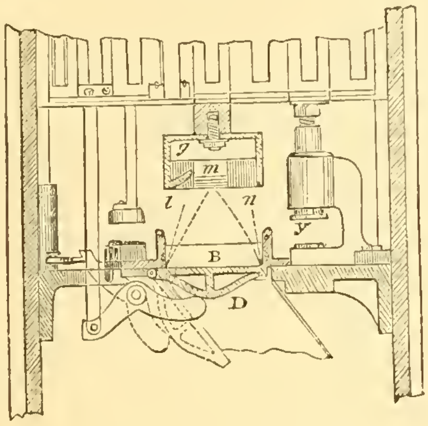
The arrangement of the mechanism is such that, a quantity of blanks of the required size being placed on the feeding-table, each will be taken up singly from the pile, and fed into the folding apparatus by means of an instrument, in which, at proper intervals, a partial vacuum is formed, whereby each sheet is sucked up against the surface of the fingers for conveyance to the folder.

As the first step of the process of folding, the flaps of the blanks are bent to a right angle by simple devices; but a novel arrangement is introduced for the performance of the secondary fold. The bottom of the creasing frame or box is perforated, so that the passing back of the plunger

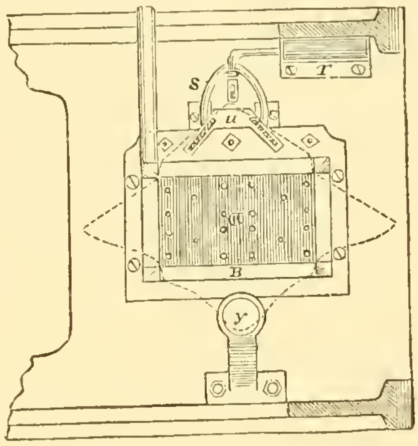
leaves the blank within the recess, with its four flaps standing upright; and here the second application of the atmospheric action comes into play, for the purpose of giving the flaps a preliminary inclination inward, in order to fit them for receiving the flat folding pressure of the return stroke of the plunger. To this end the sides of the folding-box are perforated, so as to allow streams of atmospheric air to be forced against the outsides of the flaps; so that, on the descent of the plunger, they will all be folded down at once, the interior and under surface of the plunger being suitably formed to cause the flaps to succeed each other in their proper order. In addition to this, certain contrivances are adapted for stamping the outer flaps with an embossed or perforated device, and also for gumming the lowest flap as a fastening for the completed envelope.

*B*, Fig. 1528, is the folding-box, or recess, in which the folding process is performed. It consists of

1528.



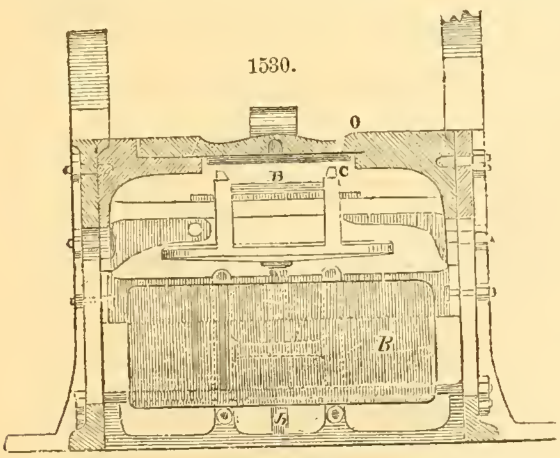

1529.



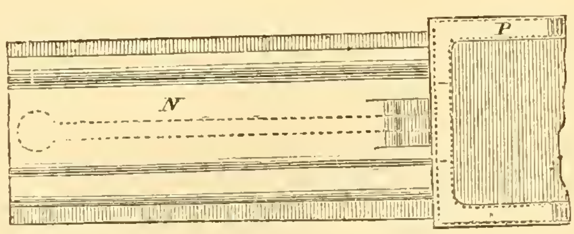

4 side-pieces, at the angles of which are projections between which the blanks are successively fed so that they may be correctly placed, and held during the action of the plunger. *D* is the door or movable bottom of the box, hinged at one end, so that, when an envelope has been folded in the box, it may be discharged below; it is perforated with numerous holes for the escape of the air, as the blank is forced down, and is kept closed by means of a lever *E*, which is actuated at the proper intervals of time by means of the cam on the main shaft, giving motion to a slide. The feeder *N*, Fig. 1527, is carried upon a slide, having dovetailed edges, moving between fixed guiding dovetails. It consists of two hollow fingers, each having an opening on the under side; the interior of the fingers opens into the hollow portion of the slide, allowing of a partial vacuum being obtained within the fingers when the exhaust movement comes into use. A flexible tube *Q*, of vulcanized India-rubber, is attached to the under side of the slide, the opposite end being connected with the bellows *R*. When the under side of the fingers comes upon the top of the pile of blanks, the exhausting action is brought into play, and the top sheet is carried over to the top of the box *B* for deposit. At the termination of the outward stroke of the bellows, the sheet is separated from them by the action of a valve in the bellows, opening outward at the commencement of the return stroke.

As the blanks are fed into proper position, the folding plunger *g*, Fig. 1528, comes into action. It is a hollow rectangular metal frame, having in its interior a set of three projections, which, in the secondary movement, act on the separate flaps, folding them all down at once, when they are held in the required inclined position by the atmospheric side currents, as previously detailed. The inclined projections are essentially necessary, in order that the flaps may be folded down in their proper relative positions; the projection *l*, pressing on one of the side flaps, causes it to be folded first; afterward the projection *m* acts upon one of the ends, while the third, *n*, carries down the opposite one, the

1530.




1531.




final folding being completed by the under edges of the plunger, which gives a sharp pressure to the initiatory fold of the whole series. By suitably setting these projections, any order may be given to the flaps; thus, if the two end ones do not overlap each other, they may be folded down together by equal projections.

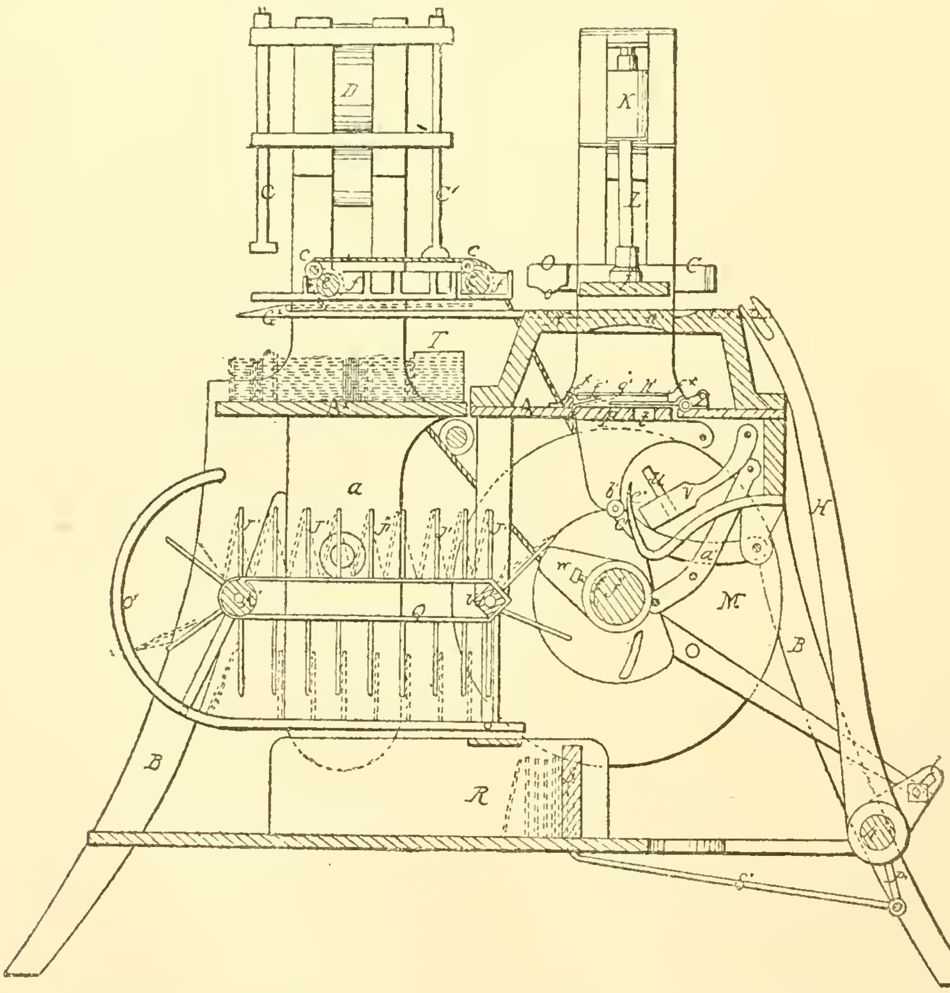
The necessary atmospheric side pressure on the flaps is obtained from the inclined air-pump *p*, the

piston of which is driven by a crank-pin on the fly-wheel; and a tube *q* conveys the forced air from the bottom of the pump to a hollow channel passing all round the edges of the folding-box, as dotted in the plan, Fig. 1529, whence the orifices, already pointed out, open inward to the box. For the application of gum or other cementing fluid to the lowest flap, to secure the three stationary ones, a fountain is placed at *r*, from the bottom of which two tubes *s s* branch out to the two flat tubular receptacles *t t* inclosed in a vessel *u*, the supply being regulated by a stop-cock before the junction of the two supply branches. The gumming action is performed by pieces of sponge placed in the upper ends of the flat tubes *t t*, which stand slightly above their upper edges; the presser *v*, descending just before the plunger, presses the edges of the lowest flap upon the sponge, as clearly illustrated in the plan view. This presser receives its motion from the cam *w* acting on the slide *x*, to which the presser is attached. If it is intended to stamp or emboss the outer flap with an embossed or perforated device, dies are applied as at *y z*. The die *y* being attached to a slide 1, acted on by the external cam 2, the stamping action takes place just before the descent of the plunger.

This machine is said to have produced easily 60 envelopes per minute, or 36,000 per day, completed, gummed, and stamped, and might probably be worked faster.

Since the first anticipations of the value of the envelope for general consumption, many modifications have been introduced. In 1844 Mr. Wilson, the inventor of the cutting machine, hit upon the ingeniously simple mode of economizing the paper in cutting out the blanks, by cutting the original web of paper diagonally across its width. Formerly, when the web was divided longitudinally, and then by transverse cuts at right angles, the rectangular sheet thus formed, when cut up into diamond pieces for the envelopes, suffered considerable loss in the reduction. By Mr. Wilson's plan this was avoided, as, the transverse cuts being all made diagonally, each blank fitted exactly to its neighbor, and this source of loss was removed. In 1846, again, Mr. Charles Chinnock obtained a patent for some contrivances for the obtainment of greater security of inclosure, by applying the ordinary postage-stamp, or other adhesive labels, so as to become a fastener for the edges of the paper forming the envelope. In one of his arrangements, a small hole, somewhat less than the area of a postage-stamp, is punched at the right-hand corner of the address side, so that, when the stamp is put on, it adheres not only to the edges of the hole, but also to the turned-in edge produced in the end fold of the envelope, as well as partially to the inclosed note. Thus the inclosure cannot be re-

1532.



moved without leaving detective marks. According to another mode, the patentee punches holes of various sizes through the parts of the envelope where the seal is placed—in some cases placing a bit of blotting-paper beneath, this being for the purpose of securing the whole by the seal. In another arrangement, the envelope is the same shape as that now generally used, having four triangular flaps, meeting in the centre for the seal. In the ends of three of these flaps are small holes, each one a little different in size, so that when folded the smallest hole is the lowest, and the largest the third

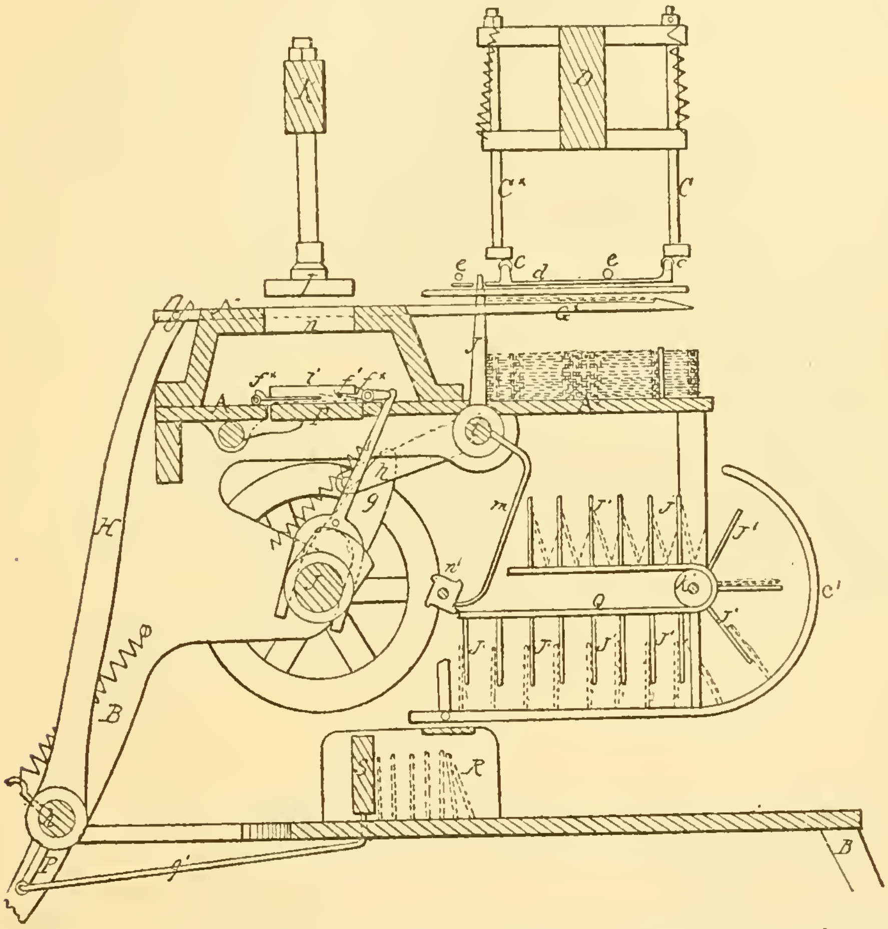
in the layers, while the fourth is blank, the wax below which not only secures all the flaps, but adheres also to the inclosure. When a piece of blotting-paper is placed below the holes, as in another modification, any attempt to open the letter would involve a tear.

In Figs. 1532 and 1533 are represented two views of the envelope machine devised by T. V. Waymouth, and manufactured by Berlin & Jones of New York.

*A* represents the bed of the machine, supported on suitable legs, *B*. The table *A'*, which supports the blanks, is detached from the main portion of the bed, and is connected to it so that it can be turned in or out. From this table *A'* rises a curved guide *T*, against which the edges of the blanks abut, so that such blanks can readily be brought into the desired position without bending up their edges. Above such table rise the pickers or gummers *C C'*, which serve to apply the gum to the blanks, and to lift one after another to be carried to the folding-machine. The gummer *C'* applies the gum to the seal-flap, and the gummer *C* to the back flap of the envelope-blank.

The gummers or pickers *C C'* are suspended from an arm *D*, extending from a slide, to which a rising and falling motion is imparted by a cam. The gummers are supplied with gum by the rollers

1533.



*c c*, which have their bearings in a reciprocating carriage *d*, by which they are alternately brought in contact with rollers *e e*, which revolve in the gum-boxes *f f*, and then are carried under the gummers. By these means the seal and back flaps of the envelope-blank are gummed at or about the same time, after the blank is put into the machine.

After the gummers have descended upon the blanks they rise again, carrying up with them the uppermost blank, which adheres to them, by reason of the nature of the gum, until such blank comes in contact with the under surface of the platform supporting the gum-box, when the blank is disengaged from the gummers or pickers and deposited on the carriers *G'*, to which a reciprocating motion is imparted by the action of an arm *H*, mounted on a rock-shaft *h'*, which rock-shaft receives an oscillating motion by means of an eccentric *i'*, mounted on the driving-shaft *j*, and connecting with such rock-shaft by a strap *k* and arm *l*.

By the carriers *G'* the blank is brought under the creasing-plunger *I*, which is secured to an arm *K*, extending from a slide *L*, to which a rising and falling motion is imparted by the action of a cam. The plunger *I* forces the blank down through an aperture *n* in the creasing-platform *N*, the blank being disengaged from the carriers, and deposited on the creasing-platform before the plunger descends, by the action of a forked lever *O*. To one of the arms of such lever is attached a die *o*, which, when brought down upon the blank while it rests upon the creasing-platform *N*, produces upon the seal-flap any mark or figure desired, as an initial letter, monogram, etc. By the descent of the plunger *I* through the aperture *n* the blank is creased, and in this condition it is brought down upon the folding-table *P*. By engraving or otherwise producing on this table, or in the face of the creasing-plunger, or in both, a suitable or desired design or die, the body of the envelope can be embossed or stamped with any desired character or pattern.

As soon as the plunger has ascended a sufficient distance from the platform *P*, the folding-wings

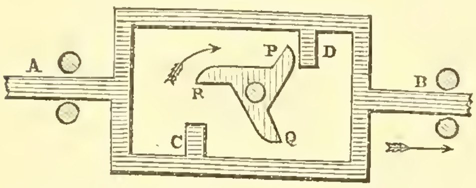
$f' g' h' i'$ turn down in quick succession, the wings $g' i'$ turning down first, and folding down the end flaps; then the wing $h'$, folding the back flap; and lastly the wing $f'$, which folds the seal-flap. The wings $g'$, $i'$, and $h'$, after having been turned down, remain stationary until the seal-flap is turned down, and such wings are so shaped that the gummed part or edge of the seal-flap will not be allowed to come in contact with any of the other flaps, and consequently such seal-flap will be prevented from adhering to the other part of the envelope.

After the operation of folding a blank has been completed, as before described, the folding-wings turn back to their original position, and the folding-table $P$ is tilted, causing the folded envelopes to slide from off such table, and drop one by one into or between two of the radiating arms or plates $j'$, which project from an endless apron $Q$. The envelopes, on being discharged from the apron, drop into a receiving-box $R$, which is provided with a follower $S$, by which they are slightly compressed, so as to be ready to be put into bundles or packages.

The endless apron on which the envelopes pass is usually made longer than is here represented, and is provided with a small blower beneath it, which creates an air-blast to dry the paste of the envelopes during their passage. An ingenious arrangement of fingers has also been contrived to take the envelopes one at a time from the apron, and place them in piles. This machine is capable of folding and pasting envelopes at the rate of about one a second.

ESCAPEMENT. A wheel fitted with teeth which are made to act upon two distinct pieces or *pallets* attached to a reciprocating frame, so arranged that when one tooth escapes, or ceases to drive a pallet, the other shall begin its action. One of the most simple forms is shown in Fig. 1534. A sliding frame, $A B$, is furnished with two projecting pieces at $C$ and $D$, and within it is centered a wheel possessing three teeth, $P$, $Q$, and $R$, which tends always to turn in the direction indicated by the arrow. The upper tooth, $P$, is represented as pressing upon the projection $D$, and driving the frame to the right hand: when the tooth $P$ escapes, the action of $Q$ commences upon the other side of the frame, and the projection $C$ is driven to the left hand. Thus the rotation of the wheel causes a reciprocating movement in the sliding piece $A B$. It is clear that the wheel must have 1, 3, 5, or some odd number of teeth upon its circumference.

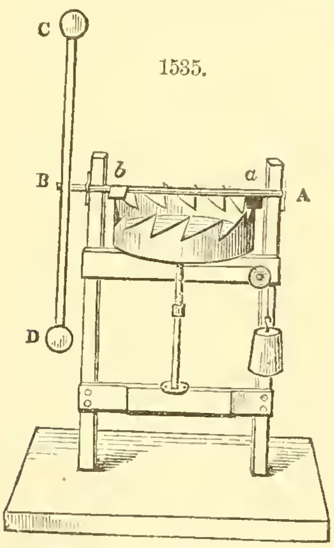
1534.



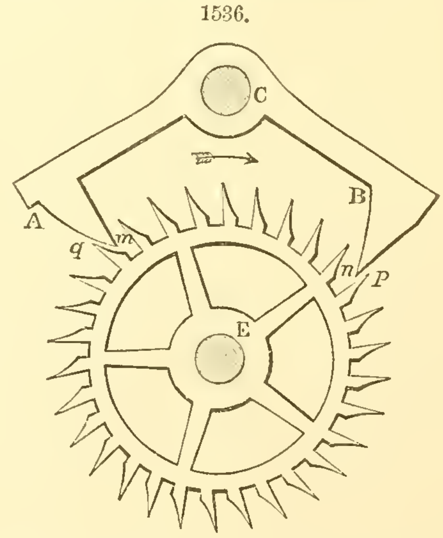

The *crown-wheel escapement* is a circular band, with large saw-shaped teeth cut upon one edge; the vibrating axis $A B$, Fig. 1535, carries two flat pieces of steel, $a$ $b$, called pallets, which project from the axis in directions at right angles to each other, and engage alternately with teeth upon the opposite sides of the wheel. Suppose the wheel to turn in the direction toward which the teeth incline, and let one of its teeth encounter the pallet $b$ and push it out of the way; as soon as $b$ escapes, a tooth on the opposite side meets the pallet $a$, and tends to bring the axis $A E$ back again; thus a reciprocating action is caused.

In the *anchor escapement* a wheel centered at $E$ is provided with a number of teeth, and tends always to turn in the direction indicated by the arrow. A portion of this wheel is embraced by an anchor, $A C B$, Fig. 1536, centered at $C$, the extreme ends of which are formed into pallets, $A m$ and $B n$: these pallets may be flat or slightly convex, but they are subject to the condition that the perpendicular to $A m$ shall pass above $C$, and the perpendicular to $B n$ shall pass between $C$ and $E$. The point of a tooth is represented as having escaped from the pallet $B n$ after driving the anchor to the right hand; and the point $q$, by pressing against $A m$, is supposed to have already pushed the anchor a little to the left hand, and thus the wheel can only proceed by causing a vibratory motion in the anchor, $A C B$. (See "Elements of Mechanism," Goodeve, New York, 1877.)

1535.




1536.




ETCHING. The apparatus required consists of copper plates, etc., etching-needles, hand-rest, etching-ground, dabber, oil-rubber, rottenstone, smoking-taper, engraver's shade, bordering-wax, stopping-out varnish, tracing-paper, aquafortis, etc.

*Ground.*—The ground is composed of asphaltum, Burgundy pitch, and beeswax. Take equal portions of the above-named materials, place them in an earthen pipkin in an oven, and melt them. The

mass must be kept stirred until well incorporated; any small piece of wood will answer this purpose. When well mixed, it must be poured into a basin of cold water, and when nearly cold should be pressed and rolled with the hand, that all the water may be discharged, then made into a ball. Procure a piece of worn silk, but be careful it is without holes, double it, place the ball therein, and tie up the ends with packthread, taking care that the double silk reaches well over the ball. When tied tight, cut off the overplus silk, and let the knot remain for a hand-hold. Be sure that the silk is tight over the ball.

*Dabber.*—Take another piece of silk, twice the size of the last, double it, place in it a ball of coarse wool well picked out, about the size of a small apple, tie it up in the same way as the ball for the ground, and it is ready for use.

*Oil-Rubber.*—The next thing necessary is an oil-rubber, which is simply a strip of woolen cloth, about 2 inches wide, rolled up tight, and bound over with packthread or thin tape. With a sharp knife cut off one end, avoiding the string, so that the surface may be quite flat. This is used for taking out stains or polishing the plate.

*Rottenstone.*—Procure a piece of fine flannel, rather less than the silk which covers the etching-ground ball, double it, place on it a small quantity of rottenstone in powder, which tie up in a bag. A small portion of fine whiting in the lump should be kept at hand for the sake of cleanliness: any small box will answer this purpose.

*Smoking-Taper.*—Procure a wax taper, uncoil it by degrees before the fire until it is all equally pliant; double it up in about six lengths, give it one twist while warm, and turn it a few times before the fire, that the pieces of taper may adhere to each other; melt the wax at one end, so that the wick is exposed; see that all the cotton ends will light freely. Care should be taken to extinguish the cotton, or it will revive with the least draught, and may become dangerous.

*Bordering-Wax.*—This may be obtained ready-made, but engravers make it to their own liking. The component parts are 3 ounces of rosin, 2 ounces of beeswax, and such a quantity of sweet oil as will soften the mixture to your fancy. Procure an earthen pipkin, place in the bottom a small quantity of sweet oil (half an ounce or more), add your rosin and beeswax, broken in small pieces; when melted, work the ingredients well together with a stick until thoroughly incorporated, then pour into a basin of cold water; as it gets cold, work it well with the hands by pulling out into lengths and doubling it together again: the more it is worked the better it will be for use. Should it turn out brittle, return it broken to the pipkin, and add more oil; work it well together as before; pour it into water, and work it again with your hands.

*Engraver's Shade.*—The next thing required is a shade, which can be made of wire. Bend it to a half-circle, bind it together with waxed string, lay it on tissue paper, cut away all but half an inch round the wire, cover that half inch with paste, and turn it over the wire; when dry, the shade is complete. Fasten a light string to the centre of the half-circle, and suspend it from the window-latch when in use. This shade must be placed in a forward position, sloping before your plate, and the white light it produces will enable the lines to be distinguished as they are made by the etching-needle. It is always beneficial in doing fine work of this kind to keep the eyes well protected from direct light by a shade worn on the forehead.

*Hand-Rest.*—Any flat and thin piece of wood will answer this purpose, which is merely to keep the hand clear of the plate while at work.

*Stopping-out Varnish.*—Turpentine varnish is superior, for several reasons, to Brunswick black. Break small bits of rosin into a vial, and cover it over with spirits of turpentine to about twice the height of the rosin. Place the bottle in a small saucepan of water on the hob, near enough to the fire to make and keep the water hot; a cork may be lightly placed in the mouth of the bottle, as the mixture will require to be shaken occasionally. A small portion of this mixture should be poured into a small pot, with a little lampblack added, to give it color, and well incorporated. This last is necessary to prevent lumps; it may be done by working the mixture well together with the camel-hair pencil. You have now a good stopping-out varnish. With this varnish go over the border or margin of your plate: do this when about to put it away, and the varnish will become hard by being left a night to set. When inclined to put your plate through the process of biting-in, again go over the margin, using the same brush and mixture. You can always work it up by adding a little turpentine. When it is set so hard that you can place the finger on it without adherence, it is time to make up your wall or border of wax to hold the aquafortis.

*Aquafortis.*—Provide yourself with three half-pint bottles having glass stoppers, and two pint earthen jugs with spouts. Then obtain at the chemist's half a pound of nitric acid in bottle No. 1. Pour into bottle No. 2 rather less than the fourth of the acid; pour the bottle three parts full of water; with a slow action pass it into one of your pint jugs, and back again to the bottle, to unite it well. In bottle No. 3 put one-half of the remaining acid; water it as before; see that the nitric acid in bottle No. 1 is well stoppered, and cover it with a piece of old glove.

*Tracing, and Tracing-Paper.*—Tracing-paper of various qualities may be purchased at any depot of arts. But, in case of necessity, very good tracing-paper may be made by saturating with a camel-hair pencil the finest tissue-paper with the following mixture: Half an ounce of the balsam of Canada to one ounce of the spirits of turpentine, shaken well together in a two-ounce bottle; it requires no heat. When covered with the mixture, hang the paper on a line to dry; then wash in like manner the other side.

Place your drawing on the tracing-board (a piece of soft planed deal), over it lay the tracing-paper, fasten down with the brass-headed points, not through the drawing, but close to it, so that the pressure of the brass head secures both the drawing and tracing-paper from moving. Go carefully over all the lines of your drawing with an H pencil, occasionally placing a piece of white paper between the drawing and the tracing-paper, to ascertain that you have not neglected any part of the lines on the drawing.

*Transferring-Paper.*—This is very easily made, as follows: Take half a sheet of very fine bank-post paper, lay it on a clean place, and rub it well with the scrapings of red chalk; a small bit of sponge is good for this purpose. Apply the chalk until the paper is all of one color; then, with a piece of clean old muslin, rub the greater part of the color from the surface. The color may be renewed occasionally as the marking becomes faint.

*Testing the Ground.*—Heat one corner of your plate, and rub over it the ground, in a thin and even surface. Next apply your dabber, to make a yet more equal distribution of the ground. When cold, mark over it with a rather blunt needle (No. 3). Should the ground be brittle, and crack with the passage of the needle, add to it more beeswax; should it drag with the needle, more asphaltum; the ground will easily melt again. When a ball is made to your satisfaction, it will last a long time. The weather has considerable effect on the mixture, but the quality of the ingredients more, so that it is advisable to get the ground as perfect as you can while you have the melting-pot in use.

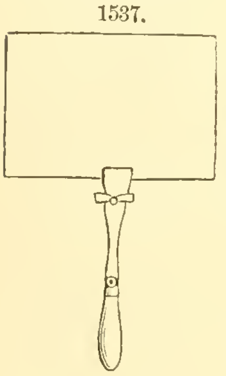
*Heating the Plate for Ground.*—You must have a small hand-vise with a haft of wood to resist the passage of heat to the hand. If your plate is stained or discolored, the mark must be removed with the oil-rubber, with a little rottenstone and oil, and polished off with a bit of old muslin powdered with whiting. Be careful that no dust remains on the plate. Screw the vise on the long side of your copper plate with a slight hold, Fig. 1537, covering the part grasped by the jaws of the vise with a small piece of paper, to prevent injury to the surface.

Heating may be performed by burning paper under the back of the plate; but a stove or clear fire is much the preferable mode. Be careful not to overheat your plate. If the surface becomes discolored, the plate is over-hot: as a test, turn it over and spit on the back; if the moisture jumps off, the plate is sufficiently hot; should it hiss and remain on the plate, more heat must be obtained.

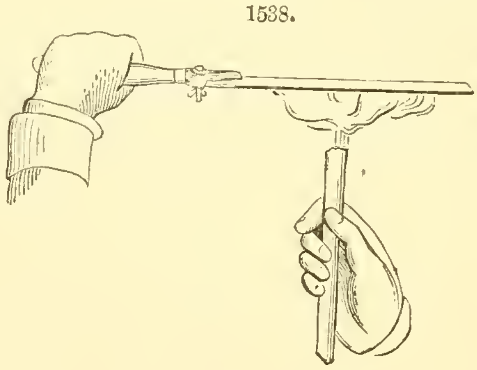
A piece of sailcloth, rather larger than the plate, should be warmed by laying it before the fire during the heating process; place it on the table, and lay upon it the plate, retaining the vise. Now pass your ball of ground over it backward and forward until the plate is covered, spreading the ground as evenly and thinly as possible. Then use your dabber with a quick action, pressing it down and plucking it up. If the ground does not distribute itself easily, burn paper under it, as before, until it shines all over, being cautious that the ashes of the paper do not settle on the surface; dab on again, decreasing the pressure but not the speed of action, until the surface is all over alike.

*Smoking the Plate.*—Have your taper ready, and a single taper or candle to take the light from; the surface of your plate being perfectly covered, it may be as well to renew the heat in your plate by a paper burnt under the back until the surface shines, taking the same precautions as before.

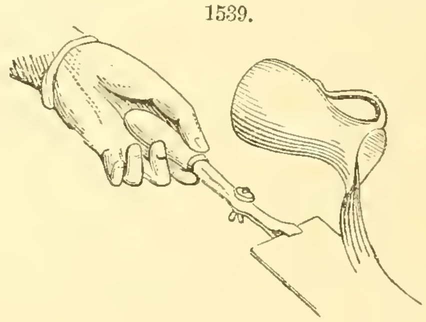
1537.



1538.



1539.



Hold the plate up in your left hand, with the face downward, as in Fig. 1538; light your smoking-taper; at the same time, having all the wicks burning, pass it rather quickly round the margin, and by degrees toward the centre, using a fluttering action with the hand; smoke on until the whole surface is of a dark color, keeping the taper at such a distance from the plate that the burning cotton may have no chance of touching it, although the flame spreads over it. When the surface is all black alike, and no sooty marks are to be seen on the working part of the plate, the ground is fit for use. Take the plate, face downward, to some convenient place, and pour cold water over the back, holding the plate in a sloping position, the vise up, Fig. 1539. This last process produces a stronger and harder surface than could be obtained if the plate were left gradually to cool. Now place the plate face downward, supported on one side by the screw of the vise, as in Fig. 1540. Clean the smoke from the back, and let it remain until quite cold.

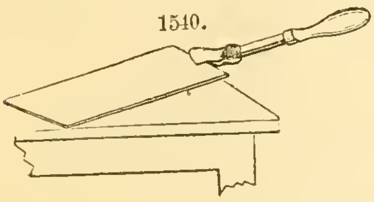
*Transferring.*—If you have not an etching-board, place your copper plate on a thick piece of brown paper, larger than the plate; make two ribs of the same paper, doubled four or more times, and about an inch wide; place them at each end of your plate on the brown paper, and fasten them with sealing-wax: these ribs serve as shoulders for *the rest* to lie on, which will prevent your hand from touching the work.

You may now cut your tracing-paper to the size of your plate, having ruled your margin line, if one is required. Place your tracing reversed, that is, the pencil side to the plate. Fix it with bits of soft wax round the border, leaving open the bottom to admit the transferring-paper, which introduces the chalk side next to the plate: the upper side of the paper must be kept clean, that you may see the pencil lines on your tracing-paper. Next, with an H H pencil, sharp and short in the cut, go over all the lines of your tracing with rather an upright hand, that you may be able to make strong pressure: the upper side of your tracing-paper, not being marked with pencil, will show whether you have gone over the whole of the lines with the pencil on the upper side; look sideways at your work, and the black-lead mark will be perceptible. Before you advance far in your transfer, lift up the bottom of your tracing to ascertain if the lines are of sufficient strength; if not, apply more red

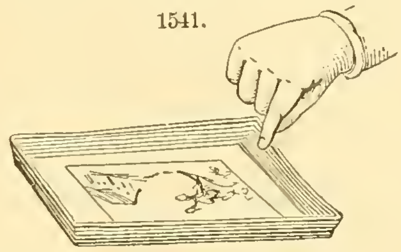
chalk to your transfer-paper. When you think the transfer is completed, do not take off the whole of your paper, but allow the part affixed by the top spots of wax to remain. You can then lift up the whole of the work, and if any part of it has been neglected the tracing can again be laid down, and the omission rectified.

*Etching.*—You must begin with needle No. 1 (the fine point) and go carefully over the outline, not making much impression on the copper, but sufficient to remove the ground; with the same point go over all the lighter parts, increasing the pressure, so that a slight indentation may be made on the plate. No. 2 point may now be used to go over the lighter shade with increased weight of hand. No. 2 point will answer for the darker shades by making the lines nearer together and increasing the

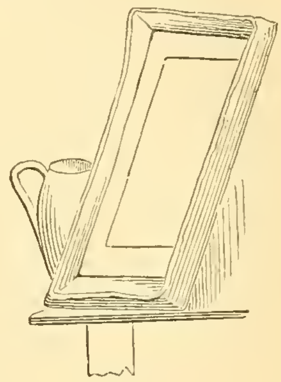
1540.



1541.



1542.



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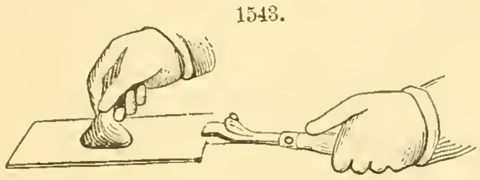


pressure. Interline parts that require extra color with No. 1 point: the etching may be worked at for a considerable time by interlining and dotting.

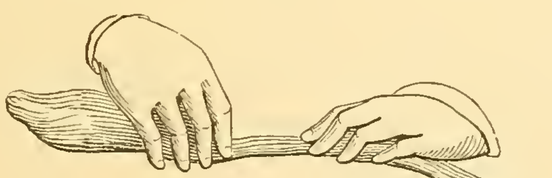
Should you by accident or mistake make any marks you wish to expunge, dip a pointed camel-hair pencil into the turpentine bottle, and with its point work up some of the ground on the margin of the plate, and therewith stop out the objectionable marks. When set it will resist the aquafortis.

*Bordering the Plate.*—In cold weather the wax will be too hard to be rolled out with the hand; it must then be placed in moderately warm water until it becomes pliable; then pull and roll it out (Fig. 1544) to about the thickness of a small walking-stick; slightly grease the point of the thumb and two forefingers with deer or mutton fat, press the roll of wax flat as you place it on the border of your plate, with the edge to the varnish, taking great care that the bordering-wax does not go off the varnish. At what you intend to be the darkest corner of your plate pinch out the wax broader, that the height of the wall may increase to that corner where the spout is to be formed with the wax, to prevent spilling the aquafortis in pouring it off. (See Figs. 1541, 1542.)

*Biting-in.*—Lay your plate flat on a piece of sailcloth larger than the plate, as a protection from any splashings that may be made. Place the spout of your plate in front for the convenience of pouring off. One of your jugs being filled with water, pour it over the plate to prove if there is any leakage in your border; should you find any, pour off the water; let the plate dry, particularly in the defective part; then press down the outer edge of the wax with a piece of stick. Lay by the side of your plate two or three wedges (small pieces of firewood), to be used for tilting the plate should the acid not lie even. It would be worse than useless to prescribe rules for the proportion of water to be used to the nitric acid, as that will entirely depend on the strength of the acid.

Having proved that your border is sound, pour off the water; then cover the surface of the plate

1544.



1545.

with the aquafortis from No. 2 bottle. If in the course of half a minute the etching on your plate should assume a light-gray coating, the mixture will do; but if it should throw up bubbles, it is over-strong, and more water must be added, but not *on the plate.* The mixture must be placed in the jug, then in the bottle, and afterward returned to the plate. Should the lines on the plate remain as bright copper after the acid has been on half a minute, it is not strong enough, and some aquafortis out of bottle No. 3 must be added.

Having mixed your aquafortis so that the lines do not produce foam, but continue a gray frosty appearance, the process is going on well. The power of biting-in correctly must depend on the experience you have of your acid. With a soft camel-hair pencil lightly remove the frosty appearance, taking care that the quill does not touch the ground. Should any part of the ground be breaking up, that is, the lines becoming united, pour off your acid carefully into the jug. Lay the plate again

on the flat, and cover it with water from the other jug, moving it gently with the camel-hair pencil, which should be placed in the water-jug when taken from the acid, or it will soon become useless. The wash-water from the plate must be thrown away. The first biting now is supposed to be completed, therefore set the plate up endways to dry.

*Second Biting.*—When the plate is perfectly dry, take off with your scraper a spot of ground in the lighter part, to ascertain if the acid has made sufficient indentation. If it has, work up your stopping-out varnish with a camel-hair pencil, and with it cover all the parts you intend to remain light; you must elevate your rest so that you do not press the border-wax. When the stopping-out varnish is dry, which may be ascertained by placing your finger on it and finding that it does not stick, put on the same aquafortis (bottle No. 2) and let it remain until you observe the ground giving way; then pour off the acid, and wash well as before. Put the plate to drain. Should it be required, more biting may be performed, and the process is the same.

*Cleaning off.*—Now comes the least agreeable part of the process. Great care must be taken that the plate is perfectly dry; if it be not, it may be placed before the fire, but not close enough to melt the wax. Having carefully wiped the sailcloth, lay the plate a little more than halfway upon it, but so that the balance remains to the table. Apply a lighted taper or a folded paper match, Fig. 1545, progressively under the wax; pull up the wax as the warmth proceeds; you will find that the slightest warmth answers the purpose. By removing the wax with a knife you are liable to injure the margin, an evil which gives much trouble to remedy. This being the most unpleasant process of engraving, it may be as well to use old gloves; if any of the wax should adhere to the plate, to remove it use a bit of deal firewood cut in the shape of a chisel. Now fix your vise on the same end, and place as you did when laying on the ground. Rub your plate over with a bit of rush candle, using the side (taking care to cover every part); have some old soft rags ready; hold the plate up by the vise; heat the back with burning paper as before, until the ground, varnish, and tallow are melted. Rub off with a soft rag. Should any smut remain, apply a little turpentine; withdraw the vise and wash the spot with turpentine. Rub the plate, front, back, and sides, with the rag. Dab the plate with your bag of rottenstone; pour on it a little sweet oil; and with your oil-rubber polish the plate with up and down strokes, using considerable pressure: wipe the plate quite clean, and polish off with fine whiting. Should you have succeeded in biting-in well, the plate is fit for the printer.

*Dry Point.*—Should your work have so far succeeded as to require but little improvement, the dry point may next be used. For this purpose the needle No. 3, well pointed (as indenture must be made by pressure of the hand), may be employed. For interlining the parts which are too weak, and uniting lines neglected in the etching, the dry point will be sufficient; but as the pressure will leave a projection or burr on the plate, it must be carefully removed by the sharp scraper. Should your plate require more than the dry point can accomplish, recourse must be had to rebiting.

*Rebiting.*—Heat your plate as before, but make one corner (the one with the least work in it) hotter than the other part. Rub your ground on the hot corner, and with the dabber take the ground therefrom, and dab quickly over the other part until the whole surface is covered. Prior to laying the ground the plate should be polished with whiting, using a piece of old muslin folded in the shape of a dabber, which will fill the etched lines, and prevent the new-laid ground from entering. All the parts but those wanting more color must be stopped out as before; again the border-wax must be used. Next follow with acid the same process.

*Re-etching.*—This is the most certain method of finishing the plate. The ground must be laid as in the first instance, but using a greater body, and with the dabber rubbing it well into the lines, taking care that no whiting remains in the etching marks; for this process the plate should be merely washed with turpentine; a slight extra warmth and good dabbing will render the ground acid-proof. The smoking is here dispensed with. Set up your shade, and work at the plate as in the first instance. Now use No. 3 point (sharp), and interline the parts you wish darker and where you want greater strength, crossing the lines, not in direct angles, but lozengewise. The plate, cleaned off as before directed, receiving a light oil-rubbing with a little rottenstone, and washed off with turpentine, may now be sent to the printer's and a proof obtained. By repeating the re-etching your plate may be worked up to the color of a line engraving. In some of the darker parts a graver or lozenge tool may be used; but as it is rather dangerous in the hands of the uninitiated, perhaps it may be best to do without it, as it is apt to slip and make deep lines where none are wanted. Rebiting will produce any extra color that may be wanted with little more trouble, and certainly with less danger.

*General Instructions.*—The following directions will relieve beginners from much trouble, and enable them to avoid many accidents to which engravers are liable.

1. When using the acid, slightly grease that part of the hand likely to come in contact with it, as a preventive to its making stains, which are not easily eradicated.

2. When your border-wax has done its duty, have it well washed in cold water, then warmed before the fire, pulled out and pressed together again, as the more frequently that is done the more flexible the wax will be for future use.

3. As your aquafortis will become reduced in strength by exposure to the air, it becomes necessary to add a portion of No. 3 bottle to that of No. 2, and a small quantity of No. 1 bottle to No. 3, No. 1 bottle being the undilute acid.

4. When making a point to your etching-needle, work your point round, as, should there be any flat side to the point, it will bite the copper and prevent the freedom of hand required to give spirit to the etching.

5. With your burnisher you may soften down any part of your etching that appears harsh or crude, by gently passing it over the parts to be reduced in color.

6. Having your shade before you, which must be between you and the light, you will be enabled to see the marks of the burnisher: fine charcoal and oil will remove them, and the oil-rubber will

clear away the charcoal marks. The charcoal can be obtained at any coppersmith's or plate-printer's.

7. If your burnisher is good at first, it never requires alteration. The scraper must be occasionally sharpened.

Soft Ground.—Take half a ball of *hard ground* (mixed as described under the head *Etching-Ground*); to that add a piece of mutton-suet. Melt them well together, observing that the mixture must be thoroughly incorporated; then pour into cold water, and use it as before directed.

*Laying the Ground.*—The process is exactly the same as in laying the etching-ground, with this difference, that the plate does not require so great a heat. Smoke the plate the same as in laying the etching-ground. The ground must be spread as thinly as it possibly can, to cover the plate and bear smoking. The surface of the plate must be alike all over, and quite bright or shining. If any part but the edges appear sooty, it must be cleared off, and the plate polished, as described for etching, and laid again. You may by chance make a good ground at the first melting, but that can scarcely be expected.

It may be as well to test the quality of your mixture before you lay a whole ground. To this end, heat a small portion of your plate; lay some of the ground; smoke it; and let it get quite cold. Obtain some of the finest tissue-paper—not fine from thinness, but from its even texture. Place a piece of the paper on the patch of ground laid, and with a fine-pointed H pencil make a slight sketch—a bit of foliage, for instance; the paper should slightly stick to the plate: when carefully raised by the two bottom corners, the back of it should clearly show every line made on its surface, only darker. Should the sketch on the copper have a grainy appearance—that is, look as if it was dotted all over—the mixture of ground will do. Should the ground adhere to the paper, like marks with pen and ink, the ground must be melted with an addition of hard ground; and if even the most tender marks of the pencil do not pull the ground from the plate, the ground must be re-melted, and so with one or the other, as the ground may require, until it is fit for work..

As the season has great effect on this ground, the one that will answer for summer will not do for winter; so it may be as well to make or procure two or three sorts of mixtures, and number them according to their several degrees of hardness.

Having succeeded in mixing your ground, take a piece of tissue-paper twice the size of your plate. Place the plate in the centre, and with a black-lead pencil draw a line all round it. Make the same mark on the other side; then lay the ground as before described. When cold, wipe the back and edges before you take off the hand-vise. This ground being very tender, care must be taken not to touch the face of the plate.

Upon the square marked on the paper your drawing is to be made. If you intend to copy the subject, you must go through the same process as in transferring for the hard-ground etching; only, instead of transferring the red lines on the plate, they must be made within the square marked on the paper. Take care that your tracing is reversed. If you intend making your drawing on the plate without copy, you must lightly make your design on the square marked with fine-pointed red chalk. Should the subject be figures, everything must be drawn, as it were, left-handed or reversed. Fold a clean silk handkerchief in four, lay it flat and smooth on the table, place it on the paper with the chalk sketch downward. Now, with great tenderness, lay the plate face down, exactly on the square mark of the paper; fold over the back the overplus paper, and fix the sides with four thin spots of sealing-wax near the corners: be sure you do not move the plate on the silk. Take your plate carefully up, and place it for work. Use a rest as in etching, and a hard pencil, H H, on the places you wish to be dark.

There is one drawback to the pleasure of soft-ground engraving: you must finish what you begin the same day; the mechanical part of the work may be delayed. Your drawing finished, pull up your paper by the two bottom corners. Varnish the border down the same as in etching. The acid used must be much stronger; the border-wax higher and broader in the spout, as you may perhaps have to pour off suddenly.

*Biting-in.*—In biting-in, the signal to pour off your acid is, when you perceive the ground breaking up—that is, coming up in patches. During the biting-in the soft camel-hair pencil may be used, but very tenderly. Wash well off with cold water, and place it to dry. For cleaning, see *Etching*, above. Should the plate require more finishing, have recourse to the hard ground without smoking.

Aquatint Engraving.—In this we have another variety of entertaining engraving; one, moreover, which, unlike the last, is still much practised by professional engravers. It forms the groundwork of many of the best modern prints, and is generally resorted to where the object is to produce a plate, the impressions from which are to be colored. It will at once be recognized by its similarity to an India-ink or sepia drawing; for in working the plate at press, black and brown inks are used indifferently, as the artist or publisher may direct. Rosin forms the ground in this method of engraving.

*Aquatint Ground.*—Break some of the best white rosin into pieces sufficiently small to go into the mouth of the bottle used. Fill the bottle up, or nearly so, with spirits of wine. This must be occasionally shaken, until the rosin is dissolved. The bottles must have corks, not glass stoppers. Have two other bottles ready; mark the bottles 1, 2, 3. No. 1 is the bottle in which the rosin is placed. Pour from the mixture No. 1 into No. 2 one-third; fill this bottle nearly with spirits of wine. Pour into No. 3 bottle rather less of the mixture from No. 1, and nearly fill it with spirits of wine. These bottles must be occasionally shaken, and their contents allowed to settle well before use. The contents of the three bottles must be so mixed that they are one under the other in strength, as the size of the grain to be laid on the plate depends on the quantity of rosin each mixture contains. The more of rosin the larger the grain. The spirit must be entirely free from water.

To test the spirit, place a small quantity of gunpowder in a silver spoon; pour over it some of the spirit; light the spirit, and let it burn down to the powder. If the powder takes fire and ex-

plodes, the spirit is good, and fit for use. If it should remain in the bottom of the spoon black and wet, the spirit has been adulterated with water, and it is not fit for the purpose.

*Trial of Aquatint Ground.*—Have a tin trough about two inches wide and rather longer than your plate, with a convenient spout at one end; the trough is to act as a receiver of the spirit when poured over the plate, the spout to return it to the bottle.

*Laying the Ground.*—Polish the plate well, as before directed. Place it on a slight slope, the tin trough under the lower edge to receive the spare mixture. As a trial of your ground, pour the liquid from each bottle, and make a small patch in different places at the bottom of your plate. When the liquid has run off to your tin trough lay the plate flat, and with a piece of rag wipe the lower edge. Take a magnifying-glass and look at the grains deposited on the copper.

Having poured the spirit from the trough to bottle No. 1, make choice of the grain most likely to suit your work, if indeed either of the three should; if not, you must mix the large grain and the small together until it does, letting the mixture settle well before it is used. When you have made one bottle of ground to suit your purpose, make a memorandum of the circumstance upon the bottle.

Having removed your trial spots, polish the plate well, and place it as directed for trial, with the side you intend for the foreground next to the tin trough. Pour the mixture along the top of the plate, from one end to the other, until the whole of the surface is covered. As soon as the spirit has run into the tin, lay the plate flat: the sooner it is laid flat, the rounder will be the setting of the grain; the longer the plate remains on the slope, the more elongated the deposit of rosin will become, which, for some sorts of work, will answer better than round—such as broken rock, waterfalls, etc.

In most cases it is advisable to make a very fine etching of the subject intended to be placed on the plate prior to laying the aquatint ground; in the end it will save time. The etching must be very light, otherwise the aquatint ground will hang round the lines and form a ray of light. Should the etching be strong, it will require to be filled up with wax, and polished off before laying the ground. Engravers send the plate to the printer's, and have it filled up with ink, which is much the best method, where it can be resorted to. If obliged to use wax, the plate must be heated rather above what is required for the etching-ground, the surface wiped off, and polished with the soft part of the hand slightly rubbed with whiting.

Having laid the ground to your satisfaction, the next proceeding is stopping out the lights.

*Stopping out the Lights.*—Place on the left side a small looking-glass in a stooping-forward position; lay before it the drawing intended to be worked from, with the base or foreground toward the bottom of the glass; you will then see the subject reversed in the glass, which will enable you to copy with greater freedom. Go over the margin as directed under the head *Etching*. For this a camel-hair pencil, and the same pot of varnish, with a little more lampblack added, and well worked together, should be used. Stop out all the white lights you observe in the drawing. By the time you have done this the varnish on the margin will be dry or set; if not, the plate must remain until it is. Then go over the margin again with the same varnish, and let that set hard. Now place up your border-wax as before directed, making the spout rather larger, that you may be enabled to pour off the acid quickly, if necessary. Use the same aquafortis as for etching, but the strength somewhat increased, as it will have to remain on the plate a much shorter time. Lay your plate an inch or so over the front of the table, with the piece of sailcloth underneath, having small wedges of wood ready to be used should the acid not float evenly (Fig. 1547).

Put on the acid rather quickly, running it from the bottle to the jug, then on the plate; the other jug, having been filled with cold water, should be kept ready for washing off. When the acid has entirely covered the plate, the surface should immediately assume a frosty appearance, but not come up in bladders. Little more than a minute may be enough for the acid to remain on the plate; pour it into the jug as quickly as you can without spilling it; immediately wash off with cold water; have a receiver for the wash-water, as it must be thrown away.

Wait until the surface of the plate is dry. If in a hurry, blow it dry with bellows. When you adjust your plate for work, should any spots of moisture remain on the surface, carefully take them up with blotting-paper. Now, with the same varnish, stop out all the second lights. To prevent injury to your border, place two blocks or old books under the ends of your rest. When the second stopping-out is set, put the plate through the same process with the same acid. Again dry the plate, and stop out the third light parts; when set, apply the acid, but let it remain on rather longer; wash, etc., as before directed. You will now have all the flat tints, and only require the very dark ones. With your magnifying-glass ascertain if the spots of rosin remain on the plate; if so, it will bear biting again. Should the ground remain sound enough to stand another application of the acid, you must prepare a mixture called touching-stuff.

*Touching-Stuff.*—Burn a good-sized cork to ashes, and take a piece of whiting about the size of a filbert; mix them together with molasses; then add as much ivory-black as will make the mixture a dark color, by the addition of a small quantity of sheep's or ox gall; it works almost as free as the varnish. Make the composition to a lump. A small quantity to be used with water when required.

Again lay the plate for work. Paint over all the parts that are required to be very dark, such as projecting foliage, and all sharp shadows, with the touching-stuff. We say paint, for you must load all the touches with as much of the mixture as can be placed on them. When the touching-stuff is dry, mix some thin turpentine varnish, slightly colored with lampblack, and with a larger brush go over the whole of the plate. When this last varnish is set, pour on some very weak acid and water; the former washings of the plate will do. With the soft camel-hair pencil used for the acid, work up the touching-stuff until the whole comes off; then wash the plate clean with cold water, and again apply the acid. For this last biting the acid may remain on the plate as long as the ground will stand. This may be ascertained by clearing your plate with the camel-hair pencil, and using the magnifying-glass. The plate must now be cleaned. Release your border-wax as before described. On this tint the oil-rubber should be very carefully used (Fig. 1546). The plate being quite clean,

place it under the shade. You will find your tints or bitings rather sharper against each other than you wish. The burnisher is to do away with this by rubbing with pressure the parts to be reduced in color. The parts to be burnished should be slightly touched with the oil-rubber. Aquatint engraving requires some skill in the use of the burnisher, which can only be acquired by practice. The scraper will be found very useful for bringing out sharp lights and modulating the darker parts.

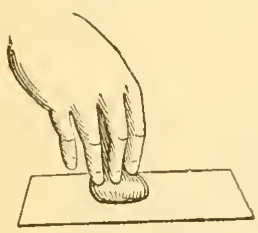
Should you have failed in making the first ground tell to your satisfaction, the plate must be polished, and another ground laid. The second ground must be larger than the first, that is, contain more rosin. The bordering, biting, and stopping-out are as before. The plate should be sent for proof before the second ground is laid. When you have the proof you will be able to ascertain where you require increase and where reduction of color. The burnisher must reduce; the increase can only be had by laying another ground.

*Ground to Etch on.*—Mix a small quantity of turpentine varnish with turpentine very slightly colored with black, but only sufficiently so to render the lines made by the needle perceptible. With this thin varnish and a good-sized camel-hair brush, go over the plate lengthwise; when that is set, repeat the coating crosswise; let it set, and lay it by for a night, if convenient. The etching finished, border and bite as before directed, but with stronger acid.

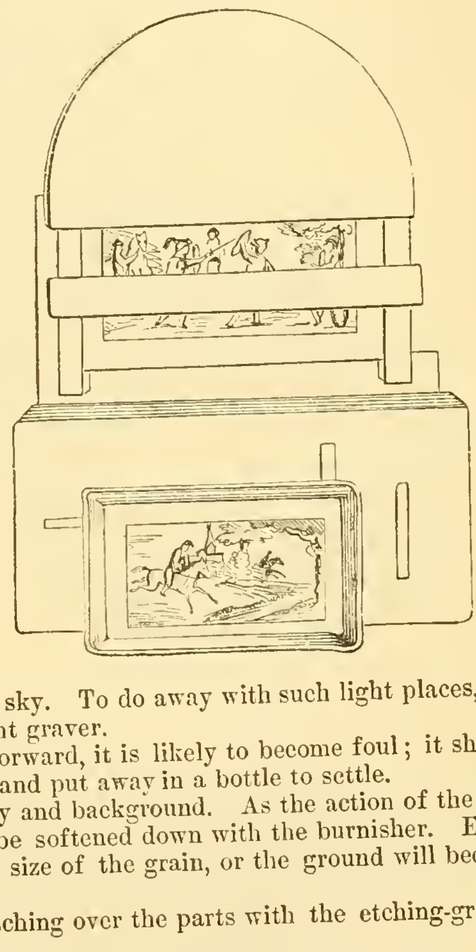
*Incidental Instructions.*—A few hints or cautions, apparently on trifles, may be found useful, and enable the beginner to avoid many troublesome obstacles which, neglected, prevent engraving from becoming an entertaining amusement.

Great care must be taken, while laying the ground, that there is not much dust floating in the air; for should the slightest particle of flock lodge on the plate while wet, it will cause what the engravers call "an accident." Wherever the speck falls, the rosin will corrode around it, and consequently form a white spot on the ground where the acid has been applied. These "accidents" are

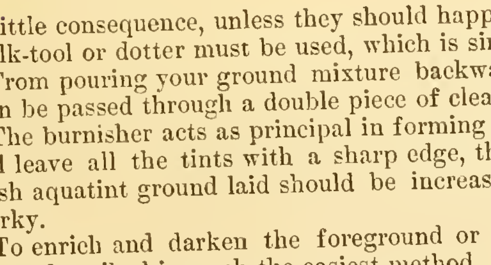
1546.



1547.



1548.



of little consequence, unless they should happen on the sky. To do away with such light places, the chalk-tool or dotter must be used, which is simply a bent graver.

From pouring your ground mixture backward and forward, it is likely to become foul; it should then be passed through a double piece of clean muslin, and put away in a bottle to settle.

The burnisher acts as principal in forming a good sky and background. As the action of the acid will leave all the tints with a sharp edge, they must be softened down with the burnisher. Every fresh aquatint ground laid should be increased in the size of the grain, or the ground will become murky.

To enrich and darken the foreground or foliage, etching over the parts with the etching-ground above described is much the easiest method.

Rosin-Ground Engraving.—This style of engraving is well adapted to ornamental work, as great depth of color can be obtained. The process is extremely simple. The best white rosin should be reduced to powder by pestle and mortar, then placed in a fine doubled flannel, and tied up in a bag. The plate must be heated as in laying etching-ground, and the bag of rosin then powdered on the surface. The best plan is to lay the plate on a table, so that you may use both hands. With the bag of rosin pendent in the right hand, strike it against the left (the bag must be held some distance from the plate), which will force the powdered rosin to escape from the flannel bag, and, falling on the hot plate, it will there fix itself in small spots, something similar to the aquatint deposit, but much more enduring. (Fig. 1548.) The stopping-out process is exactly the same as in the aquatint. By repeating the process with the flannel bag a positive black ground may be procured, as dark as and more enduring than a mezzotint ground, which may be scraped on much in the same way.

The preceding figures represent the apparatus, and the hand-craft to bring it into action—such as heating the plate, laying the ground, smoking the ground, bordering the margin, biting-in the etching, taking off the border, and polishing the plate.

Etching on Glass.—The glass is covered with a thin ground of beeswax, and the design being drawn with the etching-needle, it is subjected to the action of sulphuric acid sprinkled over with pounded fluor or Derbyshire spar. After 4 or 5 hours this is removed, and the glass cleaned off with oil of turpentine, leaving the parts covered with the beeswax untouched. This operation may be inverted by drawing the design on the glass with a solution of beeswax and turpentine, and subjecting the ground to the action of the acid.

Stippling is also executed on the etching-ground by dots instead of lines made with the etching-needle, which, according to the intensity of the shadow to be represented, are made thicker and closer. The work is then bit in.

Etching on Steel is executed much in the same way as in the process on copper. The plate is bedded on common glazier's putty, and a ground of Brunswick black is laid in the usual way, through which the needle scratches. It is then bit in, in the way above described.

EVENER. See Cotton-spinning Machinery.

EXCAVATING MACHINES. Apparatus for the removal of earth in large quantities. The ordinary method of ascertaining the nature of the material to be excavated, previous to the undertaking of any piece of earthwork, is by boring a vertical hole of about 3½ to 4 inches diameter in the ground, and bringing up specimens of the materials pierced through at different depths. For this examination, when made in rocky ground, the diamond drill is largely employed, as is explained under Rock-Drills. The best method is to combine shafts with boring by sinking at least one shaft, which should be at the point of greatest depth, and then making the borings at least 200 or 300 yards apart. Boring-tools for earth will be found described under Well-boring. See also Tunneling. A cutting is usually commenced by making a "gullet" or vertical-sided excavation, wide enough to contain one or more lines of temporary rails for the passage of cars. The widening of the cutting to its full width, and the formation of the slope, should be carried on so as never to be far behind the head or most advanced end of the gullet; for the strain thrown on a mass of earth by standing for a time with a vertical face has a tendency to produce cracks, which may extend beyond the position of the intended slopes, and so render the sides of the cutting liable to slip after they have been finished. The advanced end of a cutting of considerable depth, and the parts of its sides whose slopes have not been finished, consist, while the work is in progress, of a series of steps or stages called "lifts," rising one above another by 6 or 8 feet, or thereabouts, the excavators working at the faces of these lifts so as to carry them on together. From faces at the end or sides of the gullet, the earth is shoveled directly into the carts or cars. From the other faces of the cutting the earth is wheeled in barrows along planks to points from which it can be tipped into the wagons. The labor of excavating or getting the earth depends mainly upon its adhesion. Loose sand and gravel, soft vegetable mould, and peat can be dug with the shovel or the spade alone; stiffer kinds of earth require to be loosened with the pick before being shoveled into barrows, and in some cases with crowbars, wedges, or stakes; the softest kinds of rock can be broken up with pick or crowbar; harder kinds require the action of wedges; harder still, especially if free from natural fissures, need blasting by gunpowder or other explosives.*

The loosening of the material in shallow cuttings and in light soils is best done by the plough. In deep cuttings, the earth, being undermined at the ends, falls by itself. For short distances, 10 to 20 feet, the earth, if loose and dry, may be moved by shovels; from 20 to 200 feet, barrows may be employed running over a plank; for over 200 feet, carts will be found more economical; and for hauls over 500 feet, where a large amount of work is to be done, a track, with cars drawn by horses, will be found profitable.†

Very complete data on the subject of cost of earthwork, etc., will be found in papers on the subject by Mr. Ellwood Morris in the *Journal of the Franklin Institute*, vol. ii., 3d series, page 164; also in "A New Method of Calculating the Cubic Contents of Excavations and Embankments by the Aid of Diagrams," by J. C. Trautwine, C. E. See also the works of Rankine and Vose, previously quoted.

In order to execute an excavation with speed and economy, it is necessary to fix correctly both the absolute and the proportionate numbers of pickmen, shovelers, and barrowmen, so that all shall be constantly employed. The only method of doing this exactly is by trial on the spot. Approximately one excavator to 5 or 6 feet of breadth of face is about as close as the men can be placed without getting in each other's way. The proportion of wheelers to shovelers may be estimated approximately by the fact that a shoveler takes about as long to fill an ordinary barrow with earth as a wheeler takes to wheel a full barrow about 100 or 120 feet on a horizontal plank, and return with the empty barrow. The number of barrows required for each shoveler is one more than the number of wheelers. The proportion of pickmen to shovelers (in a single rank) depends on the stiffness of the earth; hard clay requires 2 pickmen to 1 shoveler. An earth wagon holds about as much as 50 wheelbarrows. The transverse slopes of cuttings and embankments depend upon the nature of the soil in which the work is carried on. Gravel will stand at a slope of 1½ horizontal to 1 vertical, and in some cases at 1¼ to 1. Clay, though remaining at a high angle when first cut, finally assumes a very flat slope, even as low as 4 to 1. The manner in which slips occur upon high slopes of clay or clayey earths suggests that the proper form to be given to the cross-section of the cutting is that of a parabola, flatter toward the bottom of the slope, where the pressure is greatest, and steeper above. Care should in all cases be taken to secure good drainage and to protect the slopes of the earthwork.

Fig. 1549 represents the New Jersey excavator, which is designed to excavate earth, gravel, peat, and marl; also to dig large trenches, levees, and canals for irrigating and other purposes. It is claimed to be able to dig a trench 4 to 6 feet wide and 3 feet deep, and from 400 to 600 feet long,

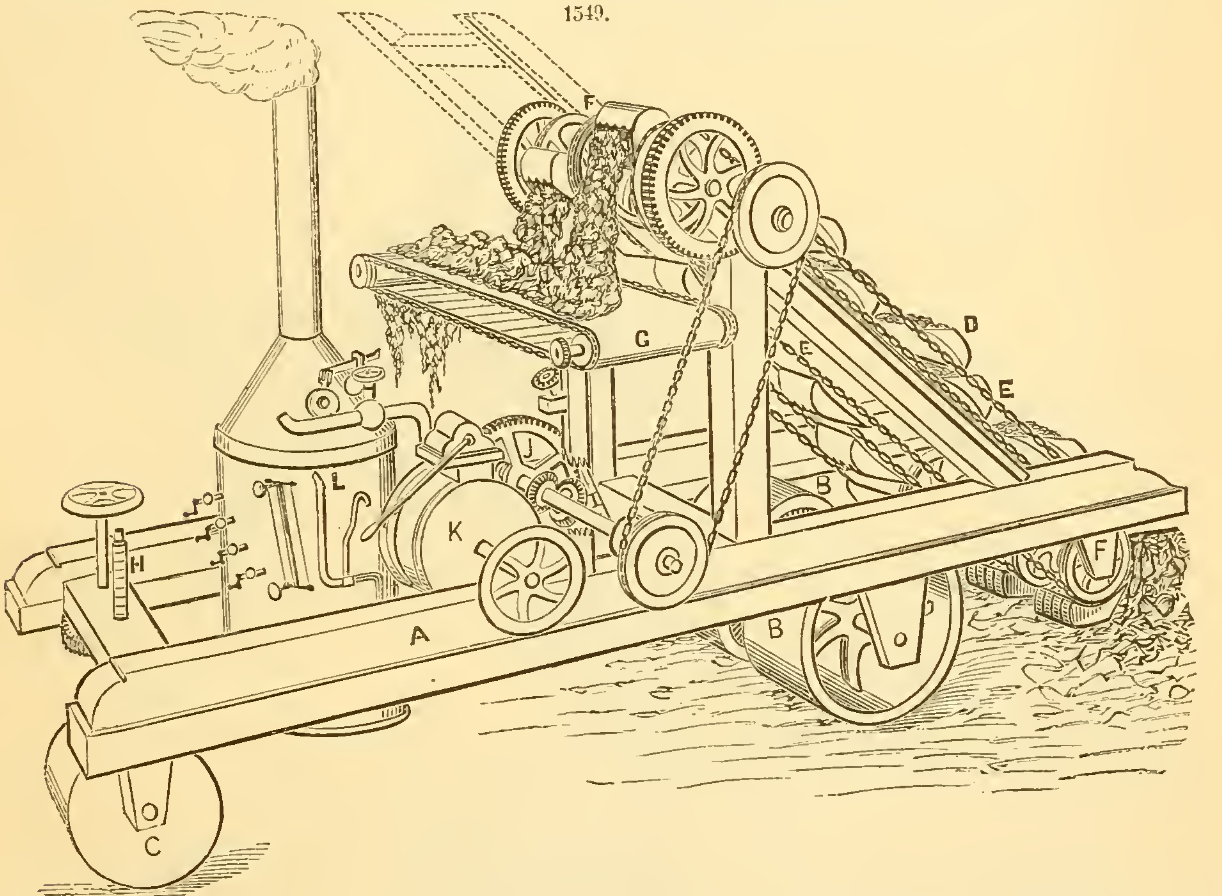
* Rankine's "Civil Engineering."

† Vose's "Manual for Railroad Engineers."

or to remove a proportionate amount of earth from a bank, in one day, at a cost for labor and fuel of not over \$6. It is also claimed to excavate 1 cubic yard of earth per minute from a 4-foot trench. It was patented in 1876 by Mr. J. P. Bonnell. The engraving is explained by the following references: *A*, the frame; *B B*, propelling traction-wheels; *C*, caster-wheel, for guiding the machine when traveling, to which is attached screw *H*; *D*, three rows of buckets faced with cast-steel knives; *E*, the four chains to which the buckets are attached; *F F*, upper and lower chain-wheels, over which the bucket-chains revolve, the upper of which are provided with lugs cast upon their periphery in order to give a positive motion to the chains; *G*, off-bearer, an endless revolving apron for depositing the earth to the side and at distance required; *H*, screw in connection with revolving nut (not seen in the engraving), worked by brake-wheel adjoining, for regulating the grade; *I*, pinion, in connection with gear *J*, for transmitting power to traction-wheels *B B*; *K*, rotary engine; *L*, boiler.

The excavator is represented in the act of entering the ground. The rear end of frame *A* is raised by screw *H* at an angle sufficient to lower the forward or digging end (which is suspended) to a contact with the ground; but a few feet advance is required to attain the necessary depth; the rear of frame is then lowered until the bottom of the trench is made parallel with the surface of the ground. The machine may be permitted to dig itself up on to the surface by a further lowering of the rear end of frame. The digging is performed by the buckets *D* attached to chains *E* revolving around the upper and lower chain-wheels *F F*. At the lower or digging point the concave backs of the buckets firmly rest, while working in the earth, against the periphery of the lower chain-wheels;

1549.




they then pass up, performing merely the functions of elevators, carrying the earth to the upper chain-wheels, at which point, in passing to return, they deposit their load upon the off-bearer *G*, which carries it to the side at any desired distance from the machine, dropping it upon the bank into cars or carts. The machine is carried forward to its work by means of the traction-wheels *B B*, in connection with the pinion *I* and gear *J*. The excavation made is sufficiently wide to permit the machine to pass through.

Fig. 1550 represents Dunbar & Ruston's steam navvy, which is used in connection with wagon roads on each side. This is one of the most recently improved forms of this machine. As the machine advances, excavating its own gullet, it fills alternately, first on the one side and then on the other, one of the empty wagons in position for being filled. The lines of rails are arranged for the wagons so that there is always a train of empty wagons standing on a central road behind the navvy, and from whence they are drawn over a short jump-road into position on the side roads for filling, while the filled wagons run back from the machine on the side roads. The navvy is capable of excavating and filling into wagons at the rate of 60 cubic yards per hour, two men and one boy being required to work it.

This machine, as will be seen on reference to the detailed drawings, is constructed mainly of wrought-iron, so as to withstand the heavy work that it has to encounter. The mode of working it may be briefly described as follows: The engine-driver, who has the control of all the moving parts, is directed by the man who has charge of the scoop, and who stands on the circular platform at foot of the jib in front of the machine. When the jib is swung to the position required, the scoop is

lowered till the mouth of it rests upon the ground. The man on the circular platform, by means of a foot-brake and gear, holds the scoop in that position, so fixing the length of the scoop-handle from a pivot or point on the jib. The scoop is now drawn forward by means of a chain and winding-drum, thereby cutting all before it, according to the radius described by the length of the scoop-handle. As soon as the scoop is filled, the man who has charge of it eases the foot-brake, allowing it to come out of its cut. When lifted high enough, the jib is then swung round until the scoop is brought over the wagon to be filled; the attendant now, by means of a trigger-line, draws the spring catch-bolt, allowing the hinged bottom to drop down, discharging its contents into the wagon. The jib is then swung round again, the scoop lowered, and the operation repeated.

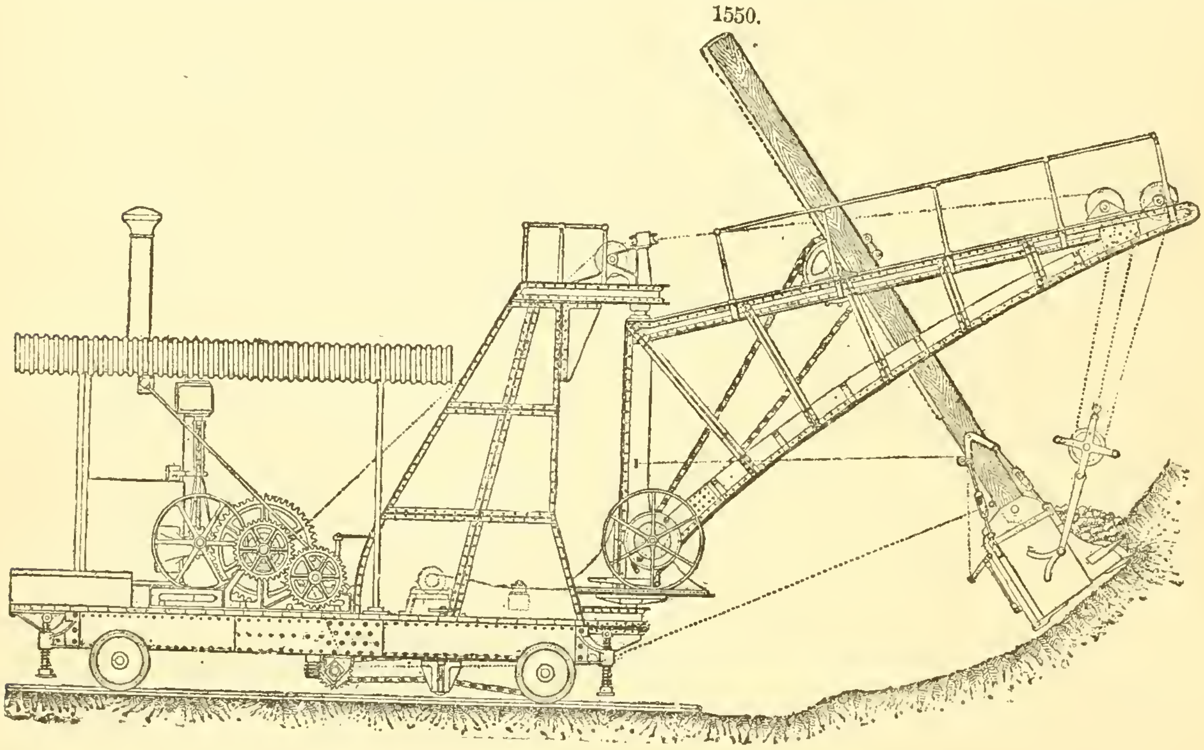
After the machine has excavated all that is within its reach, the anchor-screws are slackened off, extra sleepers with a short length of rails are laid down in front of it, and by means of the propelling gear it is moved forward the required distance. The anchor-screws are then screwed down in order to prevent the machine from slipping back when at work.

For submarine excavation, see DREDGING.

A steam digger and excavator, the invention of Mr. Otis of New York, is illustrated in the annexed figures, which present the principal side elevation (Fig. 1551) of the machine, which brings all the working parts sufficiently into view; Fig. 1552 is a plan of the horse-shoe pulley and crane top, the dotted lines showing the position of the lower framing or stage and boiler; Fig. 1553 shows the crank-shaft and gearing; Fig. 1554, the main drum; Fig. 1555, the main drum for working the excavator; and Fig. 1556, a plan of the excavator.

The machine consists of a strong horizontal wooden framing or stage *A*, mounted upon two pairs of railway wheels *b*, for locomotion, which run on temporary rails, laid down as may be required; on

1550.



the one end of the stage is fixed a cylindrical boiler *C*, and the gearing for turning the crane round. In the middle is placed the gearing for working one of the motions of the excavator *D*; and at the other end is placed the wooden crane *E*, in form similar to an ordinary timber crane, on the diagonal brace of which is placed a platform *f*, on which an assistant stands, and gearing *W* for working another motion of the excavator *D*.

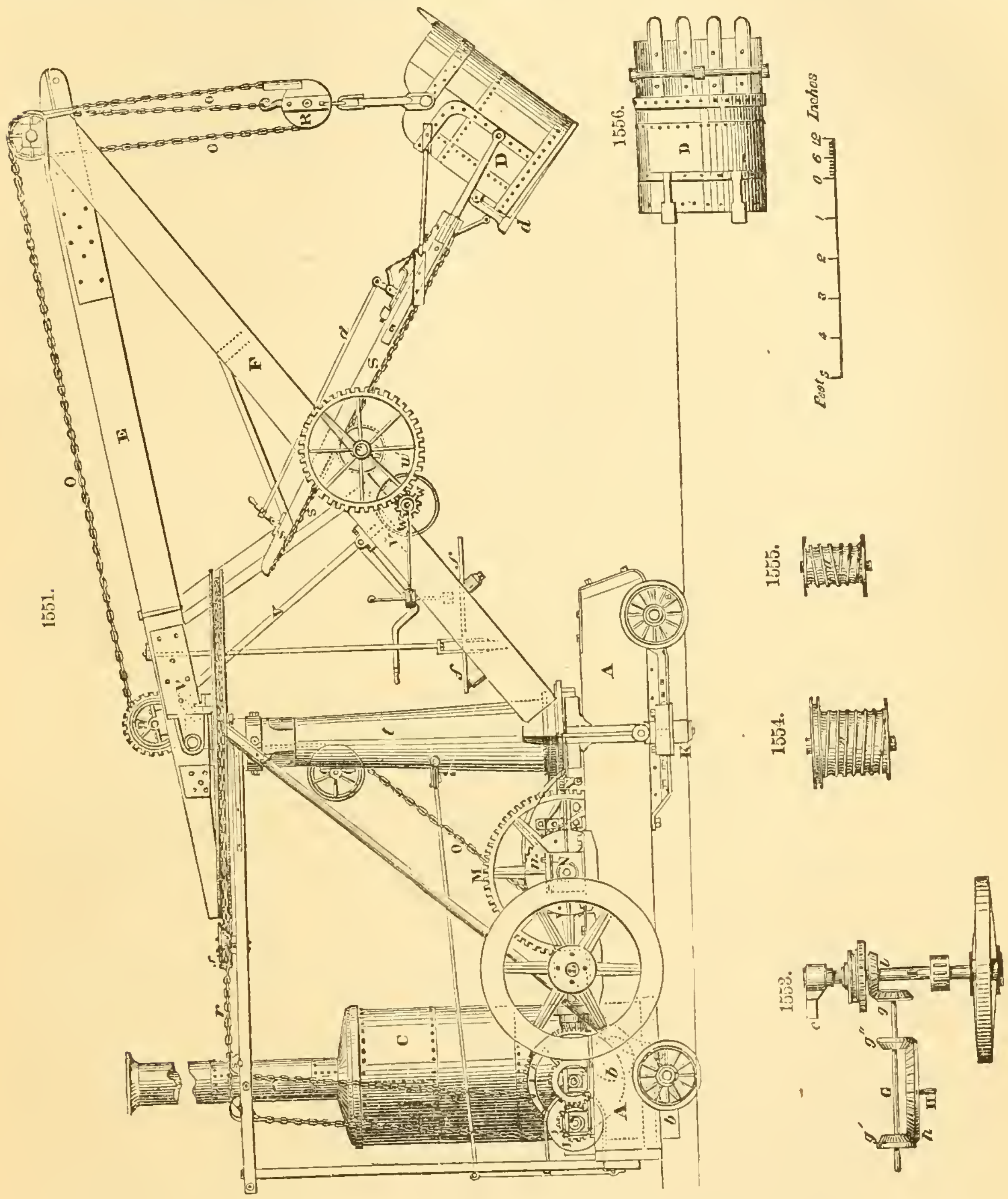
The excavator or shovel *D*, Fig. 1551, is formed of stout boiler-plate, and is firmly riveted together; it is of a box shape, having one end open: on the lower edge are four tangs or points, which serve to penetrate and loosen the soil; the other end is hung on swivel hinges, and fastened by a spring *d*, which may be set at liberty by means of the lever and rods *a*.

The machine is made to perform three distinct movements: 1, the digging movement; 2, the turning movement; 3, the locomotive movement.

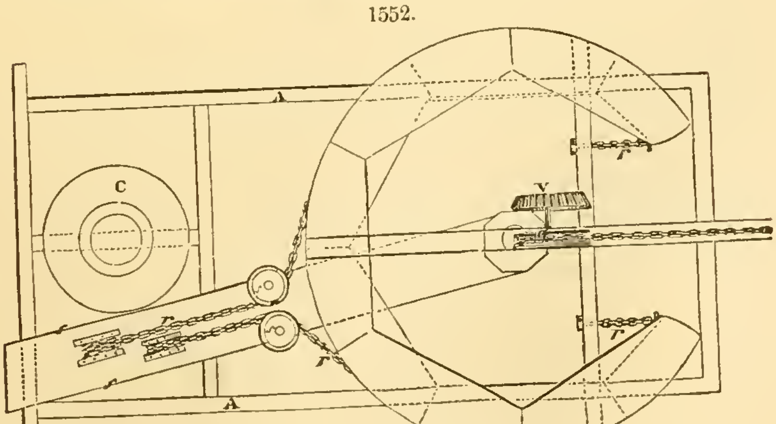
*The digging movement* consists of two motions, one for drawing the excavator forward, and the other for driving it into the ground, both of which are done simultaneously. The first motion is performed in the following manner: On the horizontal stage *A*, and in front of the boiler *C*, is placed a small high-pressure engine (not shown in the engraving), the connecting-rod of which acts upon the crank *c*, and gives a rotary motion to the shaft *L*, and with it the pinion *l*, Fig. 1553, which works into the large wheel *M*, mounted on the shaft *N*, upon which is fixed a large channeled barrel or drum *n*, Fig. 1551, round which the hauling-chain *O* is coiled; this chain passes upward through the hollow crane-post, over the indented pulley *P*, to a double pulley fixed at the jib-head, thence round the blocks *R*, to which the excavator is suspended, as the chain wound up draws the excavator out of the ground both in a forward and upward direction, when driven into the ground by the second motion. This last motion is communicated, by the chain traversing over the indented pulley *P*, to another gearing. On the axle of the indented pulley *P* is fixed a beveled wheel *v*, Fig. 1552,

which works into a similar one $v'$ mounted on to the upper end of the oblique shaft $V$, on the lower end of which is a corresponding beveled wheel $v''$, working into another $w$, fixed upon the shaft $W$; upon this shaft is a pinion $w'$, which takes into the large spur-wheel $u'$, mounted upon a shaft, upon which is a channeled drum $u$, round which is coiled the chain $s$, attached to the diagonal wooden arms

1551. 1556. 1555. 1554. 1553.



1552.



SCALE—3 inches = 16 feet.

$S$; on the lower end of these arms is fixed an iron yoke, to which is suspended on pivots the excavator. By this arrangement, as the main chain $O$ passes over the pulley $P$, motion is communicated to the shaft for the purpose of forcing downward in a diagonal direction the arms $S$, and with them the excavator into the ground. A man stands upon the stage $f$, for throwing in and out of gear this apparatus, and to regulate the motion for lowering or raising the excavator.

The next motion to be described is for the purpose of turning the crane round either to the right or to the left; this is effected by another gearing in the following manner: On the first crank-shaft $I$ is fixed a beveled wheel $l$, Fig. 1553, which works into a similar wheel $g$, mounted on to the end of a horizontal shaft $G$, upon which are placed loose two beveled wheels $g'$ $g''$, either of which can be thrown in or out of gear so as to work, as may be required, into the large beveled wheel $h$, mounted upon the shaft $H$; upon this shaft is a pinion $h'$, which works into the wheel $j$, fixed on the shaft $J$; upon this shaft is fixed an indented pulley $j'$, round which the chain $r$ is coiled, and passes upward over pulleys $s$, round either side of the horse-shoe pulley, to the ends of which it is fixed by iron bolts; the horse-shoe pulley is fixed by means of strong iron stays to the crane, and when it is made to revolve, the crane-jib is turned round on the stationary post $t$, either to the right or to the left as may be required, and empties the contents of the excavator into a wagon or barrow.

*The progressing motion* is effected by placing on the hind-wheel axle a strong wheel, shown by a circle $b$, Fig. 1551, which communicates with a pinion $b'$, on the shaft, as shown by a dotted circle; motion being given to the shaft above by the bevel-gearing described in the last motion, a forward or backward motion of the machine is obtained.

*The Couvreux Excavating Apparatus* has been largely employed in Europe, chiefly in the important work of regulating the bed of the river Danube and in the construction of the Belgian ship-canal. On the Danube this machine consisted of a chain of buckets so arranged on a frame that the empty buckets descended from above while the filled ones rose below. On reaching the emptying point these vessels were discharged by automatic mechanism. Motive power was supplied by a 20-horse engine, and the entire apparatus was mounted on a carriage running upon three rails, and propelled by a 4-horse engine. The excavated material on leaving the buckets fell into a conduit, which led it to transport-wagons running on a second and parallel railroad. (See *Engineering*, xxvi., 312.)

*Useful Data.*—Mr. Elwood Morris has determined the following useful data relative to excavation work: A horse with a loaded dirt-cart, employed in excavation or embarkment, will make 100 lineal feet of trip, or 200 feet in distance, per minute while moving. The time lost in loading, dumping, awaiting, etc., equals 4 minutes per load. A medium laborer will load with a cart in 10 hours, of the following earths, measured in the bank: gravelly earth 10, loam 12, and sandy earth 14 cubic yards. Carts are loaded as follows: descending hauling, one-eighth of a cubic yard in bank; level hauling, two-sevenths of a cubic yard in bank; ascending hauling, one-fourth of a cubic yard in bank. In loam a 3-horse plough will loosen from 250 to 800 cubic yards per day of 10 hours. A scoop-load will measure one-tenth of a cubic yard, measured in the excavation. The time lost in loading, unloading, and turning per scoop-load is $1\frac{1}{8}$ minute. The time lost for every 70 feet of distance, from excavation to bank and returning, is 1 minute. In double scooping, the time lost in loading, turning, etc., will be 1 minute; and in single scooping it will be $1\frac{1}{8}$ minute. The volume of earth in embankment is less than in excavation, from greater compression, the proportion being as follows: sand, one-seventh; clay, one-ninth; gravel, one-fourth.

See Rankine's "Civil Engineering;" also BLASTING, TUNNELING, ROCK-DRILLS, QUARRYING MACHINE, WELL-BORING, and MINE APPLIANCES.

EXHAUSTER. See GAS, ILLUMINATING, APPARATUS FOR MANUFACTURE OF.

EXPANSION OF STEAM AND GASES. *General Data.*—The formulæ and tables that follow give, in a compact form, the principal data required in calculations relating to the ordinary forms of heat-engines; and the explanations that accompany them, together with the illustrative examples, are intended to render them intelligible to all who may have occasion to use them.

Table I. is compiled from the experiments of Regnault, such calculations as were required being made in accordance with rules given in Prof. Rankine's "Treatise on the Steam-Engine." Some few remarks on the properties of steam may be appropriate in this connection.

Saturated steam is steam which is just sufficiently heated to continue in the form of vapor. If cooled at all, a portion will be condensed; and if any additional heat is imparted, the steam becomes superheated. There are three distinct phases in the change of water into steam. Suppose heat is imparted to a pound of water at 32° F., and under mean atmospheric pressure. The temperature of the water will gradually be increased until it reaches 212°, and in this process, as shown by column 3 of the table, it will receive 180.5 units of heat, or as much heat as would raise the temperature of 180.5 lbs. of water from 39° to 40°. It requires 180.5 units of heat to raise the temperature of a pound of water through a range of 180° (from 32° to 212°), because the specific heat of water increases with the temperature. To raise the temperature of a pound of water from 32° to $T°$, $T - 32 + 0.000000103 \times [(T - 39.1)^3 + (7.1)^3]$ units of heat must be imparted to it; and by this formula the quantities in column 3 of the table can be computed. When the water has attained the temperature of 212°, the process of vaporization commences; and heat is required to perform the work of overcoming the resistance of the particles of the water to the repulsion incident to the change into vapor, and also to do the work of expansion against the resistance of the atmosphere in which it is formed, so that the whole expenditure of heat in changing a pound of water at 32° into steam of 212°, as shown by column 7 of the table, is 1,146.6 units, or the sum of the quantities in columns 3, 4, and 5. By column 6, the latent heat of a pound of steam at atmospheric pressure is 966.1 units; and as this is the quantity of heat in a pound of steam evaporated "from and at 212°," the quantities in column 7 divided by 966.1 give the total heat in units of evaporation, or pounds of equivalent evaporation "from and at 212°," as shown in column 8. The other columns of this table need no particular explanation.

Table I., *showing the Properties of Saturated Steam.*

| Absolute Pressure, in Pounds per Square Inch. | Temperature, Fahrenheit Scale. | Quantity of Heat per Pound, in British Thermal Units. — Required to raise the Temperature of the Water from 32° to T. | Quantity of Heat — Required to Vaporize the Water. — To Overcome Internal Resistance to Vaporization. | Required to Vaporize the Water. — To Overcome External Resistance to Expansion. | Latent Heat of Vaporization—Sum of Columns 4 and 5. | Total Heat of Vaporization above 32°—Sum of Columns 3 and 6. | Total Heat of Vaporization above 32°, in Units of Evaporation. | Volume of a Pound of Steam, in Cubic Feet. | Weight of a Cubic Foot of Steam, in Pounds. | Relative Volume of Steam to that of Distilled Water at the Temperature of Maximum Density. | Absolute Pressure, in Pounds per Square Inch. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
| P | T | S | I | l | L | H | E | C | W | V | P |
| | Degrees. | | | | | | | | | | |
| 1 | 102.0 | 70.0 | 981.4 | 61.6 | 1,043.0 | 1,113.0 | 1.152 | 330.4 | .00303 | 20,623 | 1 |
| 2 | 126.3 | 94.4 | 962.0 | 64.1 | 1,026.1 | 1,120.5 | 1.160 | 171.9 | .00582 | 10,730 | 2 |
| 3 | 141.7 | 109.8 | 949.7 | 65.7 | 1,015.4 | 1,125.2 | 1.165 | 117.3 | .00852 | 7,325 | 3 |
| 4 | 153.1 | 121.3 | 940.6 | 66.8 | 1,007.4 | 1,128.7 | 1.168 | 89.51 | .01117 | 5,588 | 4 |
| 5 | 162.4 | 130.6 | 933.2 | 67.7 | 1,000.9 | 1,131.5 | 1.171 | 72.56 | .01378 | 4,530 | 5 |
| 6 | 170.2 | 138.4 | 927.0 | 68.4 | 995.4 | 1,133.8 | 1.174 | 61.14 | .01636 | 3,816 | 6 |
| 7 | 176.9 | 145.2 | 921.7 | 69.0 | 990.7 | 1,135.9 | 1.176 | 52.89 | .01891 | 3,302 | 7 |
| 8 | 183.0 | 151.3 | 916.9 | 69.6 | 986.5 | 1,137.8 | 1.178 | 46.65 | .02144 | 2.912 | 8 |
| 9 | 188.4 | 156.7 | 912.6 | 70.1 | 982.7 | 1,139.4 | 1.179 | 41.77 | .02394 | 2,607 | 9 |
| 10 | 193.3 | 161.7 | 908.7 | 70.6 | 979.3 | 1,141.0 | 1.181 | 37.83 | .02644 | 2,361 | 10 |
| 11 | 197.8 | 166.2 | 905.1 | 71.0 | 976.1 | 1,142.3 | 1.182 | 34.59 | .02891 | 2,159 | 11 |
| 12 | 202.0 | 170.5 | 901.8 | 71.3 | 973.1 | 1,143.6 | 1.184 | 31.87 | .03138 | 1,990 | 12 |
| 13 | 205.9 | 174.4 | 898.7 | 71.7 | 970.4 | 1,144.8 | 1.185 | 29.56 | .03383 | 1,845 | 13 |
| 14 | 209.6 | 178.1 | 895.8 | 72.0 | 967.8 | 1,145.9 | 1.186 | 27.58 | .03626 | 1,721 | 14 |
| 14.7 | 212.0 | 180.5 | 893.9 | 72.2 | 966.1 | 1,146.6 | 1.187 | 26.37 | .03793 | 1,646 | 14.7 |
| 15 | 213.1 | 181.6 | 893.0 | 72.3 | 965.3 | 1,146.9 | 1.187 | 25.85 | .03869 | 1,614 | 15 |
| 16 | 216.3 | 184.9 | 890.5 | 72.5 | 963.0 | 1,147.9 | 1.188 | 24.33 | .04111 | 1,519 | 16 |
| 17 | 219.5 | 188.1 | 888.0 | 72.8 | 960.8 | 1,148.9 | 1.189 | 22.98 | .04352 | 1,434 | 17 |
| 18 | 222.4 | 191.1 | 885.7 | 73.1 | 958.8 | 1,149.9 | 1.190 | 21.78 | .04592 | 1,359 | 18 |
| 19 | 225.3 | 193.9 | 883.4 | 73.3 | 956.7 | 1,150.6 | 1.191 | 20.70 | .04831 | 1,292 | 19 |
| 20 | 228.0 | 196.7 | 881.3 | 73.5 | 954.8 | 1,151.5 | 1.192 | 19.73 | .05070 | 1,231 | 20 |
| 21 | 230.6 | 199.3 | 879.2 | 73.7 | 952.9 | 1,152.2 | 1.193 | 18.84 | .05307 | 1,176 | 21 |
| 22 | 233.1 | 201.8 | 877.3 | 73.9 | 951.2 | 1,153.0 | 1.194 | 18.04 | .05545 | 1,126 | 22 |
| 23 | 235.5 | 204.3 | 875.4 | 74.1 | 949.5 | 1,153.8 | 1.194 | 17.30 | .05781 | 1.080 | 23 |
| 24 | 237.8 | 206.6 | 873.5 | 74.3 | 947.8 | 1,154.4 | 1.195 | 16.62 | .06017 | 1,038 | 24 |
| 25 | 240.1 | 208.9 | 871.8 | 74.5 | 946.3 | 1,155.2 | 1.196 | 16.00 | .06252 | 998.4 | 25 |
| 26 | 242.2 | 211.1 | 870.1 | 74.7 | 944.8 | 1,155.9 | 1.196 | 15.42 | .06487 | 962.3 | 26 |
| 27 | 244.3 | 213.2 | 868.4 | 74.8 | 943.2 | 1,156.4 | 1.197 | 14.88 | .06721 | 928.8 | 27 |
| 28 | 246.4 | 215.3 | 866.8 | 75.0 | 941.8 | 1,157.1 | 1.198 | 14.38 | .06955 | 897.6 | 28 |
| 29 | 248.4 | 217.3 | 865.2 | 75.2 | 940.4 | 1,157.7 | 1.198 | 13.91 | .07188 | 868.5 | 29 |
| 30 | 250.3 | 219.3 | 863.7 | 75.3 | 939.0 | 1,158.3 | 1.199 | 13.48 | .07420 | 841.3 | 30 |
| 31 | 252.2 | 221.2 | 862.2 | 75.5 | 937.7 | 1,158.9 | 1.200 | 13.07 | .07652 | 815.8 | 31 |
| 32 | 254.0 | 223.0 | 860.8 | 75.6 | 936.4 | 1,159.4 | 1.200 | 12.68 | .07884 | 791.8 | 32 |
| 33 | 255.8 | 224.8 | 859.4 | 75.7 | 935.1 | 1,159.9 | 1.201 | 12.32 | .08115 | 769.2 | 33 |
| 34 | 257.5 | 226.6 | 858.0 | 75.9 | 933.9 | 1,160.5 | 1.201 | 11.98 | .08346 | 748.0 | 34 |
| 35 | 259.2 | 228.3 | 856.7 | 76.0 | 932.7 | 1,161.0 | 1.202 | 11.66 | .08577 | 727.9 | 35 |
| 36 | 260.9 | 230.0 | 855.4 | 76.1 | 931.5 | 1,161.5 | 1.202 | 11.36 | .08807 | 708.8 | 36 |
| 37 | 262.5 | 231.7 | 854.1 | 76.3 | 930.4 | 1,162.1 | 1.203 | 11.07 | .09036 | 690.8 | 37 |
| 38 | 264.1 | 233.3 | 852.9 | 76.4 | 929.3 | 1,162.6 | 1.203 | 10.79 | .09266 | 673.7 | 38 |
| 39 | 265.6 | 234.8 | 851.6 | 76.5 | 928.1 | 1,162.9 | 1.204 | 10.53 | .09495 | 657.5 | 39 |
| 40 | 267.2 | 236.4 | 850.4 | 76.6 | 927.0 | 1,163.4 | 1.204 | 10.28 | .09723 | 642.0 | 40 |
| 41 | 268.7 | 237.9 | 849.3 | 76.7 | 926.0 | 1,163.9 | 1.205 | 10.05 | .09951 | 627.3 | 41 |
| 42 | 270.1 | 239.4 | 848.1 | 76.8 | 924.9 | 1,164.3 | 1.205 | 9.826 | .10179 | 613.3 | 42 |
| 43 | 271.6 | 240.8 | 847.0 | 76.9 | 923.9 | 1,164.7 | 1.206 | 9.609 | .10407 | 599.9 | 43 |
| 44 | 273.0 | 242.3 | 845.9 | 77.0 | 922.9 | 1,165.2 | 1.206 | 9.403 | .10635 | 587.0 | 44 |
| 45 | 274.3 | 243.7 | 844.8 | 77.1 | 921.9 | 1,165.6 | 1.207 | 9.207 | .10862 | 574.7 | 45 |
| 46 | 275.7 | 245.1 | 843.7 | 77.2 | 920.9 | 1,166.0 | 1.207 | 9.018 | .11088 | 563.0 | 46 |
| 47 | 277.0 | 216.4 | 842.7 | 77.3 | 920.0 | 1,166.4 | 1.207 | 9.838 | .11315 | 551.7 | 47 |
| 48 | 278.3 | 247.8 | 841.7 | 77.4 | 919.1 | 1,166.9 | 1.208 | 8.665 | .11541 | 540.9 | 48 |
| 49 | 279.6 | 249.1 | 840.6 | 77.5 | 918.1 | 1,167.2 | 1.208 | 8.498 | .11767 | 530.5 | 49 |
| 50 | 280.9 | 250.4 | 839.7 | 77.6 | 917.3 | 1,167.7 | 1.209 | 8.338 | .11993 | 520.5 | 50 |
| 51 | 282.2 | 251.6 | 838.7 | 77.7 | 916.4 | 1,168.0 | 1.209 | 8.185 | .12218 | 510.9 | 51 |
| 52 | 283.4 | 252.9 | 837.7 | 77.8 | 915.5 | 1,168.4 | 1.209 | 8.037 | .12443 | 501.7 | 52 |
| 53 | 284.6 | 254.1 | 836.8 | 77.9 | 914.7 | 1,168.8 | 1.210 | 7.894 | .12668 | 492.8 | 53 |
| 54 | 285.8 | 255.3 | 835.8 | 78.0 | 913.8 | 1,169.1 | 1.210 | 7.756 | .12893 | 484.2 | 54 |
| 55 | 287.0 | 256.5 | 834.9 | 78.0 | 912.9 | 1,169.4 | 1.211 | 7.624 | .13112 | 475.9 | 55 |
| 56 | 288.1 | 257.7 | 834.0 | 78.1 | 912.1 | 1,169.8 | 1.211 | 7.496 | .13341 | 467.9 | 56 |
| 57 | 289.3 | 258.9 | 833.1 | 78.2 | 911.3 | 1,170.2 | 1.211 | 7.372 | .13565 | 460.2 | 57 |
| 58 | 290.4 | 260.0 | 832.2 | 78.3 | 910.5 | 1,170.5 | 1.212 | 7.252 | .13789 | 452.7 | 58 |
| 59 | 291.5 | 261.1 | 831.4 | 78.3 | 909.7 | 1,170.8 | 1.212 | 7.136 | .14013 | 445.5 | 59 |
| 60 | 292.6 | 262.2 | 830.5 | 78.4 | 908.9 | 1,171.1 | 1.212 | 7.024 | .14236 | 438.5 | 60 |
| 61 | 293.7 | 263.3 | 829.7 | 78.5 | 908.2 | 1,171.5 | 1.213 | 6.916 | .14459 | 431.7 | 61 |
| 62 | 294.7 | 264.4 | 828.8 | 78.6 | 907.4 | 1,171.8 | 1.213 | 6.811 | .14682 | 425.2 | 62 |
| 63 | 295.8 | 265.5 | 828.0 | 78.6 | 906.6 | 1,172.1 | 1.213 | 6.709 | .14905 | 418.8 | 63 |
| 64 | 296.8 | 266.6 | 827.2 | 78.7 | 905.9 | 1,172.5 | 1.214 | 6.610 | .15128 | 412.6 | 64 |
| 65 | 297.8 | 267.6 | 826.4 | 78.8 | 905.2 | 1,172.8 | 1.214 | 6.515 | .15350 | 406.6 | 65 |

TABLE I. (*continued*).

| ABSOLUTE PRESSURE, IN POUNDS PER SQUARE INCH. | Temperature, Fahrenheit Scale. | QUANTITY OF HEAT PER POUND, IN BRITISH THERMAL UNITS. Required to raise the Temperature of the Water from 32° to T. | Required to Vaporize the Water. To Overcome Internal Resistance to Vaporization. | To Overcome External Resistance to Expansion. | Latent Heat of Vaporization—Sum of Columns 4 and 5. | Total Heat of Vaporization above 32°—Sum of Columns 3 and 6. | Total Heat of Vaporization above 32°, in Units of Evaporation. | Volume of a Pound of Steam, in Cubic Feet. | Weight of a Cubic Foot of Steam, in Pounds. | Relative Volume of Steam to that of Distilled Water at the Temperature of Maximum Density. | ABSOLUTE PRESSURE, IN POUNDS PER SQUARE INCH. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
| P | T | S | I | $l$ | L | H | E | C | W | V | P |
| | Degrees. | | | | | | | | | | |
| 66 | 298.8 | 268.6 | 825.6 | 78.8 | 904.4 | 1,173.0 | 1.214 | 6.422 | .15572 | 400.8 | 66 |
| 67 | 299.8 | 269.7 | 824.8 | 78.9 | 903.7 | 1,173.4 | 1.215 | 6.332 | .15794 | 395.2 | 67 |
| 68 | 300.8 | 270.7 | 824.0 | 79.0 | 903.0 | 1,173.7 | 1.215 | 6.244 | .16016 | 389.8 | 68 |
| 69 | 301.8 | 271.7 | 823.3 | 79.0 | 902.3 | 1,174.0 | 1.215 | 6.159 | .16237 | 384.5 | 69 |
| 70 | 302.8 | 272.7 | 822.5 | 79.1 | 901.6 | 1,174.3 | 1.216 | 6.076 | .16458 | 379.3 | 70 |
| 71 | 303.7 | 273.6 | 821.8 | 79.2 | 901.0 | 1,174.6 | 1.216 | 5.995 | .16679 | 374.3 | 71 |
| 72 | 304.7 | 274.6 | 821.0 | 79.2 | 900.2 | 1,174.8 | 1.216 | 5.917 | .16900 | 369.4 | 72 |
| 73 | 305.6 | 275.6 | 820.3 | 79.3 | 899.6 | 1,175.2 | 1.216 | 5.841 | .17121 | 364.6 | 73 |
| 74 | 306.5 | 276.5 | 819.6 | 79.3 | 898.9 | 1,175.4 | 1.217 | 5.767 | .17342 | 360.0 | 74 |
| 75 | 307.4 | 277.4 | 818.9 | 79.4 | 898.3 | 1,175.7 | 1.217 | 5.694 | .17562 | 355.5 | 75 |
| 76 | 308.3 | 278.4 | 818.2 | 79.5 | 897.7 | 1,176.1 | 1.217 | 5.624 | .17783 | 351.1 | 76 |
| 77 | 309.2 | 279.3 | 817.5 | 79.5 | 897.0 | 1,176.3 | 1.218 | 5.555 | .18003 | 346.8 | 77 |
| 78 | 310.1 | 280.2 | 816.8 | 79.6 | 896.4 | 1,176.6 | 1.218 | 5.488 | .18223 | 342.6 | 78 |
| 79 | 311.0 | 281.1 | 816.1 | 79.6 | 895.7 | 1,176.8 | 1.218 | 5.422 | .18443 | 338.5 | 79 |
| 80 | 311.9 | 282.0 | 815.4 | 79.7 | 895.1 | 1,177.1 | 1.218 | 5.358 | .18663 | 334.5 | 80 |
| 81 | 312.7 | 282.8 | 814.7 | 79.7 | 894.4 | 1,177.2 | 1.219 | 5.296 | .18882 | 330.6 | 81 |
| 82 | 313.6 | 283.7 | 814.1 | 79.8 | 893.9 | 1,177.6 | 1.219 | 5.235 | .19102 | 326.8 | 82 |
| 83 | 314.4 | 284.6 | 813.4 | 79.9 | 893.3 | 1,177.9 | 1.219 | 5.176 | .19321 | 323.1 | 83 |
| 84 | 315.3 | 285.4 | 812.8 | 79.9 | 892.7 | 1,178.1 | 1.220 | 5.118 | .19540 | 319.5 | 84 |
| 85 | 316.1 | 286.3 | 812.1 | 80.0 | 892.1 | 1,178.4 | 1.220 | 5.061 | .19759 | 315.9 | 85 |
| 86 | 316.9 | 287.1 | 811.5 | 80.0 | 891.5 | 1,178.6 | 1.220 | 5.006 | .19978 | 312.5 | 86 |
| 87 | 317.7 | 287.9 | 810.9 | 80.1 | 891.0 | 1,178.9 | 1.220 | 4.951 | .20197 | 309.1 | 87 |
| 88 | 318.5 | 288.8 | 810.2 | 80.1 | 890.3 | 1,179.1 | 1.221 | 4.898 | .20416 | 305.8 | 88 |
| 89 | 319.3 | 289.6 | 809.6 | 80.2 | 889.8 | 1,179.4 | 1.221 | 4.846 | .20634 | 302.5 | 89 |
| 90 | 320.1 | 290.4 | 809.0 | 80.2 | 889.2 | 1,179.6 | 1.221 | 4.796 | .20853 | 299.4 | 90 |
| 91 | 320.9 | 291.2 | 808.4 | 80.3 | 888.7 | 1,179.9 | 1.221 | 4.746 | .21071 | 296.3 | 91 |
| 92 | 321.7 | 292.0 | 807.8 | 80.3 | 888.1 | 1,180.1 | 1.222 | 4.697 | .21289 | 293.2 | 92 |
| 93 | 322.4 | 292.8 | 807.2 | 80.4 | 887.6 | 1,180.4 | 1.222 | 4.650 | .21507 | 290.2 | 93 |
| 94 | 323.2 | 293.5 | 806.6 | 80.4 | 887.0 | 1,180.5 | 1.222 | 4.603 | .21725 | 287.3 | 94 |
| 95 | 323.9 | 294.3 | 806.0 | 80.4 | 886.4 | 1,180.7 | 1.222 | 4.557 | .21943 | 284.5 | 95 |
| 96 | 324.7 | 295.1 | 805.4 | 80.5 | 885.9 | 1,181.0 | 1.222 | 4.513 | .22160 | 281.7 | 96 |
| 97 | 325.4 | 295.8 | 804.8 | 80.5 | 885.3 | 1,181.1 | 1.223 | 4.469 | .22378 | 279.0 | 97 |
| 98 | 326.2 | 296.6 | 804.2 | 80.6 | 884.8 | 1,181.4 | 1.223 | 4.426 | .22595 | 276.3 | 98 |
| 99 | 326.9 | 297.4 | 803.7 | 80.6 | 884.3 | 1,181.7 | 1.223 | 4.384 | .22812 | 273.7 | 99 |
| 100 | 327.6 | 298.1 | 803.1 | 80.7 | 883.8 | 1,181.9 | 1.223 | 4.342 | .23029 | 271.1 | 100 |
| 101 | 328.3 | 298.8 | 802.5 | 80.7 | 883.2 | 1,182.0 | 1.224 | 4.302 | .23246 | 268.5 | 101 |
| 102 | 329.1 | 299.6 | 802.0 | 80.8 | 882.8 | 1,182.4 | 1.224 | 4.262 | .23463 | 266.0 | 102 |
| 103 | 329.8 | 300.3 | 801.4 | 80.8 | 882.2 | 1,182.5 | 1.224 | 4.223 | .23680 | 263.6 | 103 |
| 104 | 330.5 | 301.0 | 800.9 | 80.8 | 881·7 | 1,182.7 | 1.224 | 4.185 | .23897 | 261.2 | 104 |
| 105 | 331.2 | 301.7 | 800.3 | 80.9 | 881.2 | 1,182.9 | 1.225 | 4.147 | .24114 | 258.9 | 105 |
| 106 | 331.9 | 302.4 | 799.8 | 80.9 | 880.7 | 1,183.1 | 1.225 | 4.110 | .24330 | 256.6 | 106 |
| 107 | 332.6 | 303.2 | 799.3 | 81.0 | 880.3 | 1,183.5 | 1.225 | 4.074 | .24547 | 254.3 | 107 |
| 108 | 333.2 | 303.9 | 798.7 | 81.0 | 879.7 | 1,183.6 | 1.225 | 4.038 | .24763 | 252.1 | 108 |
| 109 | 333.9 | 304.6 | 798.2 | 81.0 | 879.2 | 1,183.8 | 1.225 | 4.003 | .24979 | 249.9 | 109 |
| 110 | 334.6 | 305.2 | 797.7 | 81.1 | 878.8 | 1,184.0 | 1.226 | 3.969 | .25195 | 247.8 | 110 |
| 111 | 335.3 | 305.9 | 797.2 | 81.1 | 878.3 | 1,184.2 | 1.226 | 3.935 | .25411 | 245.7 | 111 |
| 112 | 335.9 | 306.6 | 796.6 | 81.1 | 877.7 | 1,184.3 | 1.226 | 3.902 | .25626 | 243.6 | 112 |
| 113 | 336.6 | 307.3 | 796.1 | 81.2 | 877.3 | 1,184.6 | 1.226 | 3.870 | .25842 | 241.6 | 113 |
| 114 | 337.2 | 308.0 | 795.6 | 81.2 | 876.8 | 1,184.8 | 1.226 | 3.838 | .26058 | 239.6 | 114 |
| 115 | 337.9 | 308.6 | 795.1 | 81.3 | 876.4 | 1,185.0 | 1.227 | 3.806 | .26273 | 237.6 | 115 |
| 116 | 338.5 | 309.3 | 794.6 | 81.3 | 875.9 | 1,185.2 | 1.227 | 3.775 | .26489 | 235.7 | 116 |
| 117 | 339.2 | 309.9 | 794.1 | 81.3 | 875.4 | 1,185.3 | 1.227 | 3.745 | .26704 | 233.8 | 117 |
| 118 | 339.8 | 310.6 | 793.6 | 81.4 | 875.0 | 1,185.6 | 1.227 | 3.715 | .26920 | 231.9 | 118 |
| 119 | 340.4 | 311.2 | 793.1 | 81.4 | 874.5 | 1,185.7 | 1.227 | 3.685 | .27135 | 230.1 | 119 |
| 120 | 341.1 | 311.9 | 792.6 | 81.4 | 874.0 | 1,185.9 | 1.228 | 3.656 | .27350 | 228.3 | 120 |
| 121 | 341.7 | 312.5 | 792.2 | 81.5 | 873.7 | 1,186.2 | 1.228 | 3.628 | .27565 | 226.5 | 121 |
| 122 | 342.3 | 313.2 | 791.7 | 81.5 | 873.2 | 1,186.4 | 1.228 | 3.600 | .27780 | 224.7 | 122 |
| 123 | 342.9 | 313.8 | 791.2 | 81.5 | 872.7 | 1,186.5 | 1.228 | 3.572 | .27995 | 223.0 | 123 |
| 124 | 343.5 | 314.4 | 790.7 | 81.6 | 872.3 | 1,186.7 | 1.228 | 3.545 | .28210 | 221.3 | 124 |
| 125 | 344.1 | 315.1 | 790.2 | 81.6 | 871.8 | 1,186.9 | 1.229 | 3.518 | .28424 | 219.6 | 125 |
| 126 | 344.7 | 315.7 | 789.8 | 81.6 | 871.4 | 1,187.1 | 1.229 | 3.492 | .28639 | 218.0 | 126 |
| 127 | 345.3 | 316.3 | 789.3 | 81.7 | 871.0 | 1,187.3 | 1.229 | 3.466 | .28853 | 216.4 | 127 |
| 128 | 345.9 | 316.9 | 788.8 | 81.7 | 870.5 | 1,187.4 | 1.229 | 3.440 | .29068 | 214.8 | 128 |
| 129 | 346.5 | 317.5 | 788.4 | 81.7 | 870.1 | 1,187.6 | 1.229 | 3.415 | .29282 | 213.2 | 129 |
| 130 | 347.1 | 318.1 | 787.9 | 81.8 | 869.7 | 1,187.8 | 1.230 | 3.390 | .29496 | 211.6 | 130 |
| 140 | 352.8 | 324.0 | 783.5 | 82.1 | 865.6 | 1,189.6 | 1.231 | 3.161 | .31634 | 197.3 | 140 |
| 150 | 358.2 | 329.6 | 779.3 | 82.4 | 861.7 | 1,191.3 | 1.233 | 2.962 | .33764 | 184.9 | 150 |

It seldom happens that the temperature of the feed-water is at 32°, and table II. contains corrections for various temperatures from 32° to 212°. To illustrate its use, suppose it is required to find the total heat in units of evaporation necessary to change a pound of water at 65° into steam having a pressure of 100 lbs. per square inch. By column 8 in table I., it appears that the total heat in units of evaporation from water at 32° is 1.223, and by table II. the correction is 0.034; so that the required quantity is $1.223 - 0.034 = 1.189$ unit of evaporation.

TABLE II., *showing Correction for Units of Evaporation—Different Temperatures of Feed-Water.*

| Temperature of Feed, Fahr. Degrees. | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | Temperature of Feed, Fahr. Deg. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 30 | .... | .... | .... | .001 | .002 | .003 | .004 | .005 | .006 | .007 | 30 |
| 40 | .008 | .009 | .010 | .011 | .012 | .014 | .015 | .016 | .017 | .018 | 40 |
| 50 | .019 | .020 | .021 | .022 | .023 | .024 | .025 | .026 | .027 | .028 | 50 |
| 60 | .029 | .030 | .031 | .032 | .033 | .034 | .035 | .036 | .037 | .038 | 60 |
| 70 | .039 | .040 | .041 | .042 | .044 | .045 | .046 | .047 | .048 | .049 | 70 |
| 80 | .050 | .051 | .052 | .053 | .054 | .055 | .056 | .057 | .058 | .059 | 80 |
| 90 | .060 | .061 | .062 | .063 | .064 | .065 | .066 | .067 | .068 | .069 | 90 |
| 100 | .070 | .071 | .073 | .074 | .075 | .076 | .077 | .078 | .079 | .080 | 100 |
| 110 | .081 | .082 | .083 | .084 | .085 | .086 | .087 | .088 | .089 | .090 | 110 |
| 120 | .091 | .092 | .093 | .094 | .095 | .096 | .097 | .098 | .099 | .101 | 120 |
| 130 | .102 | .103 | .104 | .105 | .106 | .107 | .108 | .109 | .110 | .111 | 130 |
| 140 | .112 | .113 | .114 | .115 | .116 | .117 | .118 | .119 | .120 | .121 | 140 |
| 150 | .122 | .123 | .124 | .125 | .126 | .128 | .129 | .130 | .131 | .132 | 150 |
| 160 | .133 | .134 | .135 | .136 | .137 | .138 | .139 | .140 | .141 | .142 | 160 |
| 170 | .143 | .144 | .145 | .146 | .147 | .148 | .149 | .150 | .151 | .153 | 170 |
| 180 | .154 | .155 | .156 | .157 | .158 | .159 | .160 | .161 | .162 | .163 | 180 |
| 190 | .164 | .165 | .166 | .167 | .168 | .169 | .170 | .171 | .172 | .173 | 190 |
| 200 | .174 | .175 | .176 | .178 | .179 | .180 | .181 | .182 | .183 | .184 | 200 |
| 210 | .185 | .186 | .187 | .... | .... | .... | .... | .... | .... | .... | 210 |

The weight and volume of water at different temperatures are frequently required in making calculations; and they can be deduced from the following formulæ, which are taken from Watt's "Dictionary of Chemistry," and represent the results of experiments by Kopp, Matthiessen, Sorby, and Rosetti:

Let $V =$ ratio of a given volume of distilled water, at the temperature $T$ on Fahrenheit's scale, to the volume of an equal weight at the temperature of maximum density. $W =$ weight of a cubic foot of distilled water, in pounds, at any temperature, Fahrenheit.

For temperatures from 32° to 70° F.: $V = 1.00012 - 0.000033914 \times (T - 32) + 0.0000023822 \times (T - 32)^2 - 0.000000006403\,(T - 32)^3$.

For temperatures above 70° F.: $V = 0.99781 + 0.00006117 \times (T - 32) + 0.000001059 \times (T - 32)^2$.

$$W = \frac{62.425}{V}.$$

The table given below has been computed by the aid of these formulæ. The experiments on the expansion of water have not been carried beyond a temperature of 412° F., so that the results given in the table for higher temperatures have not been verified. It is not probable, however, that they are greatly in error. The highest temperature in the table corresponds to a pressure of saturated steam of more than 1,000 lbs. per square inch. The successive increments of 10° F. give such slight changes in the successive differences in relative weights and volumes as to render interpolations by proportion sufficiently accurate for most purposes. The weights given in the tables are for pure water, so that, when water contains foreign matter, it will be necessary to multiply the tabular weight by the specific gravity of the water. For ordinary rain, spring, or river water, the correction is generally so slight that it may be neglected. Below are given the specific gravities of waters from different localities, the most of which have been taken from Professor Chandler's lecture on "Water," published in the thirty-first annual report of the American Institute:

| | | | |
|---|---|---|---|
| Atlantic Ocean | 1.0275 | Delaware River | 1.000059 |
| Dead Sea | 1.17205 | Lake Erie | 1.000107 |
| Great Salt Lake | 1.17 | Lake Michigan | 1.000113 |
| Mississippi River | 1.00068 | Genesee River | 1.000226 |
| Croton (New York water-supply) | 1.00008 | Passaic River | 1.000127 |
| Ridgewood (Brooklyn water-supply) | 1.000067 | Thames, at London | 1.000279 |
| Cochituate (Boston water-supply) | 1.000053 | Seine, above Paris | 1.000151 |
| Schuylkill (Philadelphia water-supply) | 1.00006 | | |

It will be seen from these figures that, for most cases, it will be sufficiently accurate to use the weights given in the table. If the weight of a gallon of water at any temperature is desired, it may be obtained by dividing the weight of a gallon of water at the temperature of maximum density (8.3389 lbs. for a United States gallon, and 10.001077 lbs. for an imperial gallon) by the relative volume at the required temperature. It may also be obtained by multiplying the weight of a cubic foot of water at the given temperature by 0.1335631 to find the weight of a United States gallon, and by 0.1603412 to find the weight of an imperial gallon. When water contains foreign matter in solution, its rate of expansion by heat is not exactly the same as in the case of distilled water; but there have not been experiments enough to determine the law of the variation, and no great error will arise from the assumption that the expansion is in accordance with the formulæ given above.

With these explanations, the use of the following table will be rendered plain to the reader:

TABLE III., *showing Volume and Weight of Distilled Water at Different Temperatures on the Fahrenheit Scale.*

| Temperature, Fahrenheit Degrees. | Ratio of Volume to Volume of Equal Weight at the Temperature of Maximum Density. | Difference. | Weight of a Cubic Foot in Pounds. | Difference. | Temperature, Fahrenheit Degrees. | Ratio of Volume to Volume of Equal Weight at the Temperature of Maximum Density. | Difference. | Weight of a Cubic Foot in Pounds. | Difference. |
|---|---|---|---|---|---|---|---|---|---|
| 32 | 1.000129 | ....... | 62.417 | .... | 290 | 1.08405 | .00596 | 57.585 | .318 |
| 39.2 | 1 | .000129 | 62.425 | .008 | 300 | 1.09023 | .00618 | 57.259 | .326 |
| 40 | 1.000004 | .000004 | 62.423 | .002 | 310 | 1.09661 | .00638 | 56.925 | .334 |
| 50 | 1.000253 | .000249 | 62.409 | .014 | 320 | 1.10323 | .00662 | 56.584 | .341 |
| 60 | 1.000929 | .000676 | 62.367 | .042 | 330 | 1.11005 | .00682 | 56.236 | .348 |
| 70 | 1.001981 | .001052 | 62.302 | .065 | 340 | 1.11706 | .00701 | 55.883 | .353 |
| 80 | 1.00332 | .001339 | 62.218 | .084 | 350 | 1.12431 | .00725 | 55.523 | .360 |
| 90 | 1.00492 | .00160 | 62.119 | .099 | 360 | 1.13175 | .00744 | 55.158 | .365 |
| 100 | 1.00686 | .00194 | 62 | .119 | 370 | 1.13942 | .00767 | 54.787 | .371 |
| 110 | 1.00902 | .00216 | 61.867 | .133 | 380 | 1.14729 | .00787 | 54.411 | .376 |
| 120 | 1.01143 | .00241 | 61.720 | .147 | 390 | 1.15538 | .00809 | 54.030 | .381 |
| 130 | 1.01411 | .00268 | 61.556 | .164 | 400 | 1.16366 | .00828 | 53.645 | .385 |
| 140 | 1.01690 | .00279 | 61.388 | .168 | 410 | 1.17218 | .00852 | 53.255 | .390 |
| 150 | 1.01995 | .00305 | 61.204 | .184 | 420 | 1.18090 | .00872 | 52.862 | .393 |
| 160 | 1.02324 | .00329 | 61.007 | .197 | 430 | 1.18982 | .00892 | 52.466 | .396 |
| 170 | 1.02671 | .00347 | 60.801 | .206 | 440 | 1.19898 | .00916 | 52.065 | .401 |
| 180 | 1.03033 | .00362 | 60.587 | .214 | 450 | 1.20833 | .00935 | 51.662 | .403 |
| 190 | 1.03411 | .00378 | 60.366 | .221 | 460 | 1.21790 | .00957 | 51.256 | .406 |
| 200 | 1.03807 | .00396 | 60.136 | .230 | 470 | 1.22767 | .00977 | 50.848 | .408 |
| 210 | 1.04226 | .00419 | 59.894 | .242 | 480 | 1.23766 | .00999 | 50.438 | .410 |
| 212 | 1.04312 | .00086 | 59.707 | .187 | 490 | 1.24785 | .01019 | 50.026 | .412 |
| 220 | 1.04668 | .00356 | 59.641 | .066 | 500 | 1.25828 | .01043 | 49.611 | .415 |
| 230 | 1.05142 | .00474 | 59.372 | .269 | 510 | 1.26892 | .01064 | 49.195 | .416 |
| 240 | 1.05633 | .00491 | 59.096 | .276 | 520 | 1.27975 | .01083 | 48.778 | .417 |
| 250 | 1.06144 | .00511 | 58.812 | .284 | 530 | 1.29080 | .01105 | 48.360 | .418 |
| 260 | 1.06679 | .00535 | 58.517 | .295 | 540 | 1.30204 | .01124 | 47.941 | .419 |
| 270 | 1.07233 | .00554 | 58.214 | .303 | 550 | 1.31354 | .01150 | 47.521 | .420 |
| 280 | 1.07809 | .00576 | 57.903 | .311 | | | | | |

A perfect gas is one in which the particles are absolutely frictionless in their mutual action. There are no examples of perfect gases in nature, but gases which can only be solidified by extraordinary means, such as air, nitrogen, oxygen, hydrogen, are commonly considered to follow perfect gaseous laws.* Table IV. contains the principal properties of such gases, as well as approximate data for steam. The columns relating to perfect gases will be found very useful in calculations relating to air-engines, while those referring to steam will be equally serviceable in computations connected with steam-engines, as is fully explained in the illustrative examples that follow. The quantities in this table have been calculated in the following manner: Calling any quantity in column 1 or 24, $\frac{1}{R}$, the corresponding quantities in the other columns are:

2. $R$

3. $\dfrac{1 + \text{hyp. log. } R}{R}$

4. $\dfrac{3.451 - 2.451 \times \left(\frac{1}{R}\right)^{0.408}}{R}$

5. $17 \times \dfrac{1}{R} - 16 \times \left(\dfrac{1}{R}\right)^{\frac{17}{16}}$

6. $\dfrac{\text{hyp. log. } R}{R - 1}$

7. $\dfrac{2.451 \times \left[1 - \left(\frac{1}{R}\right)^{0.408}\right]}{R - 1}$

8. $\dfrac{16 \times \left[1 - \left(\frac{1}{R}\right)^{\frac{1}{16}}\right]}{R - 1}$

9. $\dfrac{\text{hyp. log. } R}{R}$

10. $\dfrac{2.451 \times \left[1 - \left(\frac{1}{R}\right)^{0.408}\right]}{R}$

11. $\dfrac{16 \times \left[1 - \left(\frac{1}{R}\right)^{\frac{1}{16}}\right]}{R}$

12. $\left(\dfrac{1}{R}\right)^{0.408}$

13. $\left(\dfrac{1}{R}\right)^{\frac{17}{96}}$

14. $\left(\dfrac{1}{R}\right)^{0.29}$

15. $\left(\dfrac{1}{R}\right)^{\frac{1}{6}}$

16. $\left(\dfrac{1}{R}\right)^{0.408}$

17. $\left(\dfrac{1}{R}\right)^{\frac{17}{16}}$

18. $\left(\dfrac{1}{R}\right)^{3.451}$

19. $\left(\dfrac{1}{R}\right)^{6}$

20. $\left(\dfrac{1}{R}\right)^{0.71}$

21. $\left(\dfrac{1}{R}\right)^{\frac{16}{17}}$

22. $\left(\dfrac{1}{R}\right)^{2.451}$

23. $\left(\dfrac{1}{R}\right)^{\frac{96}{17}}$

* Quite recently all the so-called permanent gases have been liquefied, the discovery being announced almost simultaneously by MM. Cailletet and Pictet. To M. Cailletet, however, belongs the priority. See *La Nature*, 1877, 1878; *Journal of the Franklin Institute*, cv., cvi.; *Scientific American*, xxxviii., 147; *Scientific American Supplement*, v., 1883; *Engineering*, xxv., 324.

TABLE IV., *showing Ratio of Pressure, Temperature, and Volume of Air, Steam, and Perfect Gas.*

| GIVEN RATIO: TEMPERATURE, PRESSURE, OR VOLUME. | Inverse Ratio. | Ratio of Mean to Initial Total Pressure, for given Ratio of Volumes. | | | | | | Ratio of Total Pressure at Point of Cut-off to Portion of Ratio of Mean Total Pressure during whole Stroke that is due to Expansion, for given Ratio of Volumes. | | | Ratio of Initial and Final Temperatures: Absolute Temperature for Air; Temperature on Fahrenheit's Scale + 100° for Steam. | | | | Ratio of Initial and Final Absolute Pressures. | | | | Ratio of Initial and Final Volumes. | | | | GIVEN RATIO: TEMPERATURE, PRESSURE, OR VOLUME. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | During whole Stroke (supposing Initial Pressure and Pressure at Point of Cut-off to be identical). | | | During Expansion only. | | | | | | For given Ratio of Volumes. | | For given Ratio of Absolute Pressures. | | For given Ratio of Volumes. | | For given Ratio of Temperatures: Absolute Temperature for Air; Temperature on Fahrenheit's Scale + 100° for Steam. | | For given Ratio of Absolute Pressures. | | For given Ratio of Temperatures: Absolute Temperature for Air; Temperature on Fahrenheit's Scale + 100° for Steam. | | |
| | | Perfect Gas, Temperature Constant. | Air expanding without Loss or Gain of Heat. | Saturated Steam. | Perfect Gas, Temperature Constant. | Air expanding without Loss or Gain of Heat. | Saturated Steam. | Perfect Gas, Temperature Constant. | Air expanding without Loss or Gain of Heat. | Saturated Steam. | Air expanding without Loss or Gain of Heat. | Saturated Steam. | Air expanding without Loss or Gain of Heat. | Saturated Steam. | Air expanding without Loss or Gain of Heat. | Saturated Steam. | Air expanding without Loss or Gain of Heat. | Saturated Steam. | Air expanding without Loss or Gain of Heat. | Saturated Steam. | Air expanding without Loss or Gain of Heat. | Saturated Steam. | |
| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 |
| .01 | 100 | .0561 | .0308 | .0500 | .0465 | .0210 | .0404 | .0461 | .0208 | .0400 | .1528 | .442 | .2633 | .464 | .0015 | .0075 | .... | .... | .0380 | .0131 | .... | .... | .01 |
| .02 | 50 | .0982 | .0591 | .0894 | .0798 | .0399 | .0708 | .0782 | .0391 | .0694 | .2027 | .500 | .3219 | .521 | .0041 | .0157 | .... | .... | .0621 | .0252 | .... | .... | .02 |
| .03 | 33.333 | .1352 | .0860 | .1245 | .1085 | .0577 | .0974 | .1052 | .0560 | .0945 | .2392 | .537 | .3620 | .557 | .0072 | .0241 | .... | .... | .0829 | .0369 | .... | .... | .03 |
| .04 | 25 | .1688 | .1117 | .1566 | .1341 | .0747 | .1215 | .1288 | .0717 | .1166 | .2689 | .566 | .3935 | .585 | .0103 | .0327 | .... | .... | .1017 | .0483 | .... | .... | .04 |
| .05 | 20 | .1998 | .1365 | .1866 | .1577 | .0910 | .1438 | .1498 | .0865 | .1366 | .2946 | .588 | .4198 | .607 | .0147 | .0414 | .... | .... | .1191 | .0596 | .... | .... | .05 |
| .06 | 16.667 | .2288 | .1604 | .2148 | .1796 | .1068 | .1647 | .1688 | .1004 | .1548 | .3173 | .608 | .4425 | .626 | .0190 | .0503 | .... | .... | .1356 | .0708 | .... | .... | .06 |
| .07 | 14.286 | .2562 | .1836 | .2415 | .2002 | .1222 | .1844 | .1862 | .1136 | .1715 | .3379 | .624 | .4627 | .642 | .0237 | .0593 | .... | .... | .1513 | .0819 | .... | .... | .07 |
| .08 | 12.5 | .2821 | .2061 | .2669 | .2196 | .1371 | .2032 | .2021 | .1261 | .1869 | .3568 | .639 | .4810 | .656 | .0286 | .0683 | .... | .... | .1663 | .0928 | .... | .... | .08 |
| .09 | 11.111 | .3067 | .2280 | .2912 | .2382 | .1517 | .2211 | .2167 | .1380 | .2012 | .3744 | .653 | .4977 | .669 | .0337 | .0774 | .... | .... | .1808 | .1037 | .... | .... | .09 |
| .10 | 10 | .3303 | .2498 | .3145 | .2558 | .1659 | .2383 | .2203 | .1493 | .2145 | .3908 | .665 | .5131 | .681 | .0391 | .0866 | .... | .... | .1949 | .1145 | .... | .... | .10 |
| .11 | 9.091 | .3528 | .2701 | .3368 | .2728 | .1798 | .2548 | .2428 | .1601 | .2268 | .4063 | .676 | .5275 | .692 | .0447 | .0958 | .... | .... | .2085 | .1253 | .... | .... | .11 |
| .12 | 8.333 | .3744 | .2908 | .3583 | .2891 | .1935 | .2708 | .2544 | .1703 | .2383 | .4210 | .687 | .5410 | .702 | .0505 | .1051 | .... | .... | .2218 | .1359 | .... | .... | .12 |
| .13 | 7.692 | .3952 | .3100 | .3790 | .3049 | .2069 | .2862 | .2652 | .1800 | .2490 | .4350 | .697 | .5537 | .712 | .0566 | .1144 | .... | .... | .2348 | .1466 | .... | .... | .13 |
| .14 | 7.143 | .4153 | .3293 | .3990 | .3201 | .2201 | .3012 | .2753 | .1893 | .2590 | .4484 | .706 | .5657 | .721 | .0628 | .1238 | .... | .... | .2475 | .1572 | .... | .... | .14 |
| .15 | 6.667 | .4346 | .3481 | .4183 | .3348 | .2331 | .3157 | .2846 | .1981 | .2683 | .4612 | .715 | .5771 | .729 | .0692 | .1332 | .... | .... | .2599 | .1677 | .010 | .... | .15 |
| .16 | 6.25 | .4532 | .3665 | .4370 | .3491 | .2458 | .3298 | .2932 | .2065 | .2770 | .4735 | .723 | .5880 | .737 | .0758 | .1427 | .... | .... | .2721 | .1782 | .011 | .... | .16 |
| .17 | 5.882 | .4712 | .3845 | .4552 | .3629 | .2584 | .3436 | .3012 | .2145 | .2852 | .4853 | .731 | .5984 | .744 | .0825 | .1522 | .... | .... | .2841 | .1887 | .013 | .... | .17 |
| .18 | 5.556 | .4887 | .4020 | .4727 | .3764 | .2708 | .3570 | .3087 | .2220 | .2927 | .4968 | .738 | .6084 | .751 | .0894 | .1617 | .... | .... | .2959 | .1991 | .015 | .... | .18 |
| .19 | 5.263 | .5055 | .4192 | .4897 | .3896 | .2830 | .3700 | .3155 | .2292 | .2997 | .5079 | .745 | .6180 | .758 | .0965 | .1713 | .... | .... | .3074 | .2095 | .017 | .... | .19 |
| .20 | 5 | .5219 | .4360 | .5062 | .4024 | .2950 | .3828 | .3219 | .2360 | .3062 | .5186 | .752 | .6273 | .765 | .1037 | .1809 | .... | .... | .3188 | .2199 | .019 | .... | .20 |
| .21 | 4.762 | .5377 | .4524 | .5223 | .4149 | .3069 | .3953 | .3277 | .2424 | .3123 | .5290 | .759 | .6362 | .771 | .1111 | .1905 | .... | .... | .3301 | .2302 | .022 | .... | .21 |
| .22 | 4.545 | .5531 | .4685 | .5378 | .4271 | .3186 | .4075 | .3331 | .2485 | .3178 | .5392 | .765 | .6448 | .777 | .1186 | .2001 | .... | .... | .3412 | .2405 | .024 | .... | .22 |
| .23 | 4.348 | .5680 | .4842 | .5530 | .4390 | .3302 | .4194 | .3380 | .2542 | .3230 | .5490 | .771 | .6532 | .783 | .1263 | .2098 | .... | .... | .3521 | .2508 | .027 | .... | .23 |
| .24 | 4.167 | .5825 | .4996 | .5677 | .4507 | .3416 | .4312 | .3425 | .2596 | .3277 | .5586 | .777 | .6613 | .788 | .1341 | .2195 | .... | .... | .3629 | .2610 | .030 | .... | .24 |
| .25 | 4 | .5966 | .5147 | .5820 | .4621 | .3529 | .4426 | .3466 | .2647 | .3320 | .5680 | .782 | .6692 | .794 | .1420 | .2293 | .008 | .... | .3736 | .2712 | .033 | .... | .25 |

TABLE IV. (*continued*).

| GIVEN RATIO: TEMPERATURE, PRESSURE, OR VOLUME. | Inverse Ratio. | Ratio of Mean to Initial Total Pressure, for given Ratio of Volumes. | | | | | | Ratio of Total Pressure at Point of Cut-off to Portion of Ratio of Mean Total Pressure during whole Stroke that is due to Expansion, for given Ratio of Volumes. | | | Ratio of Initial and Final Temperatures: Absolute Temperature for Air; Temperature on Fahrenheit's Scale + 100° for Steam. | | | | Ratio of Initial and Final Absolute Pressures. | | | | Ratio of Initial and Final Volumes. | | | | GIVEN RATIO: TEMPERATURE, PRESSURE, OR VOLUME. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | During whole Stroke (supposing Initial Pressure and Pressure at Point of Cut-off to be identical). | | | During Expansion only. | | | | | | For given Ratio of Volumes. | | For given Ratio of Absolute Pressures. | | For given Ratio of Volumes. | | For given Ratio of Temperatures: Absolute Temperature for Air; Temperature on Fahrenheit's Scale + 100° for Steam. | | For given Ratio of Absolute Pressures. | | For given Ratio of Temperatures: Absolute Temperature for Air; Temperature on Fahrenheit's Scale + 100° for Steam. | | |
| | | Perfect Gas, Temperature Constant. | Air expanding without Loss or Gain of Heat. | Saturated Steam. | Perfect Gas, Temperature Constant. | Air expanding without Loss or Gain of Heat. | Saturated Steam. | Perfect Gas, Temperature Constant. | Air expanding without Loss or Gain of Heat. | Saturated Steam. | Air expanding without Loss or Gain of Heat. | Saturated Steam. | Air expanding without Loss or Gain of Heat. | Saturated Steam. | Air expanding without Loss or Gain of Heat. | Saturated Steam. | Air expanding without Loss or Gain of Heat. | Saturated Steam. | Air expanding without Loss or Gain of Heat. | Saturated Steam. | Air expanding without Loss or Gain of Heat. | Saturated Steam. | |
| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 |
| .26 | 3.846 | .6102 | .5295 | .5959 | .4733 | .3641 | .4539 | .3502 | .2695 | .3359 | .5772 | .788 | .6768 | .799 | .1501 | .2390 | .010 | .... | .3841 | .2814 | .037 | .... | .26 |
| .27 | 3.704 | .6235 | .5439 | .6094 | .4843 | .3752 | .4650 | .3535 | .2729 | .3394 | .5861 | .793 | .6843 | .804 | .1583 | .2488 | .011 | .... | .3946 | .2916 | .040 | .... | .27 |
| .28 | 3.571 | .6364 | .5580 | .6226 | .4950 | .3861 | .4759 | .3564 | .2780 | .3426 | .5949 | .798 | .6915 | .809 | .1666 | .2586 | .012 | .... | .4049 | .3018 | .044 | .... | .28 |
| .29 | 3.448 | .6490 | .5718 | .6355 | .5056 | .3970 | .4866 | .3590 | .2818 | .3455 | .6035 | .803 | .6986 | .814 | .1750 | .2684 | .014 | .... | .4151 | .3119 | .048 | .... | .29 |
| .30 | 3.333 | .6612 | .5854 | .6479 | .5160 | .4077 | .4971 | .3612 | .2854 | .3479 | .6119 | .808 | .7055 | .818 | .1836 | .2783 | .016 | .... | .4252 | .3220 | .052 | .... | .30 |
| .31 | 3.226 | .6731 | .5986 | .6601 | .5262 | .4183 | .5074 | .3631 | .2886 | .3501 | .6201 | .813 | .7122 | .828 | .1922 | .2881 | .018 | .... | .4353 | .3321 | .057 | .... | .31 |
| .32 | 3.125 | .6846 | .6116 | .6719 | .5362 | .4288 | .5176 | .3646 | .2916 | .3519 | .6282 | .817 | .7188 | .827 | .2010 | .2980 | .020 | .... | .4452 | .3422 | .061 | .... | .32 |
| .33 | 3.03 | .6959 | .6243 | .6835 | .5461 | .4393 | .5276 | .3659 | .2948 | .3535 | .6361 | .822 | .7252 | .831 | .2099 | .3079 | .022 | .... | .4550 | .3522 | .066 | .... | .33 |
| .34 | 2.941 | .7068 | .6367 | .6947 | .5558 | .4496 | .5374 | .3668 | .2967 | .3547 | .6439 | .826 | .7315 | .835 | .2189 | .3178 | .024 | .... | .4648 | .3623 | .071 | .... | .34 |
| .35 | 2.857 | .7174 | .6489 | .7056 | .5653 | .4598 | .5471 | .3674 | .2989 | .3556 | .6516 | .830 | .7377 | .839 | .2281 | .3278 | .027 | .... | .4744 | .3723 | .076 | .... | .35 |
| .36 | 2.778 | .7278 | .6608 | .7163 | .5747 | .4700 | .5567 | .3678 | .3008 | .3563 | .6591 | .835 | .7438 | .843 | .2373 | .3377 | .029 | .... | .4840 | .3823 | .082 | .... | .36 |
| .37 | 2.703 | .7379 | .6724 | .7267 | .5839 | .4800 | .5662 | .3679 | .3024 | .3567 | .6665 | .839 | .7497 | .847 | .2466 | .3477 | .032 | .... | .4935 | .3923 | .087 | .... | .37 |
| .38 | 2.632 | .7477 | .6838 | .7368 | .5930 | .4900 | .5755 | .3677 | .3038 | .3568 | .6738 | .843 | .7555 | .851 | .2561 | .3577 | .035 | .... | .5030 | .4023 | .093 | .... | .38 |
| .39 | 2.564 | .7572 | .6949 | .7466 | .6020 | .4999 | .5846 | .3672 | .3049 | .3566 | .6810 | .846 | .7612 | .855 | .2656 | .3677 | .039 | .... | .5124 | .4122 | .099 | .... | .39 |
| .40 | 2.5 | .7665 | .7058 | .7562 | .6109 | .5097 | .5937 | .3665 | .3058 | .3562 | .6881 | .850 | .7668 | .858 | .2752 | .3777 | .042 | .... | .5216 | .4222 | .106 | .... | .40 |
| .41 | 2.439 | .7756 | .7165 | .7656 | .6196 | .5194 | .6026 | .3656 | .3065 | .3556 | .6951 | .854 | .7723 | .862 | .2850 | .3878 | .046 | .... | .5309 | .4321 | .112 | .... | .41 |
| .42 | 2.381 | .7844 | .7269 | .7747 | .6282 | .5291 | .6115 | .3644 | .3069 | .3547 | .7019 | .858 | .7777 | .865 | .2948 | .3978 | .050 | .... | .5400 | .4420 | .119 | .... | .42 |
| .43 | 2.326 | .7929 | .7370 | .7835 | .6367 | .5386 | .6202 | .3629 | .3070 | .3535 | .7087 | .861 | .7831 | .869 | .3047 | .4079 | .054 | .... | .5491 | .4519 | .126 | .... | .43 |
| .44 | 2.273 | .8012 | .7470 | .7921 | .6451 | .5481 | .6288 | .3612 | .3070 | .3521 | .7154 | .865 | .7883 | .872 | .3148 | .4180 | .059 | .... | .5582 | .4618 | .134 | .... | .44 |
| .45 | 2.222 | .8093 | .7567 | .8005 | .6533 | .5576 | .6373 | .3593 | .3067 | .3505 | .7220 | .868 | .7934 | .875 | .3249 | .4281 | .064 | .008 | .5672 | .4716 | .141 | .011 | .45 |
| .46 | 2.174 | .8172 | .7662 | .8087 | .6615 | .5670 | .6457 | .3572 | .3062 | .3487 | .7285 | .872 | .7985 | .879 | .3351 | .4392 | .069 | .009 | .5761 | .4815 | .149 | .012 | .46 |
| .47 | 2.128 | .8249 | .7754 | .8166 | .6696 | .5762 | .6540 | .3549 | .3054 | .3466 | .7349 | .875 | .8035 | .882 | .3454 | .4483 | .074 | .011 | .5850 | .4913 | .157 | .014 | .47 |
| .48 | 2.083 | .8323 | .7845 | .8244 | .6775 | .5855 | .6622 | .3523 | .3045 | .3444 | .7412 | .878 | .8084 | .885 | .3558 | .4585 | .079 | .012 | .5938 | .5012 | .165 | .016 | .48 |
| .49 | 2.041 | .8395 | .7933 | .8319 | .6854 | .5947 | .6703 | .3495 | .3033 | .3419 | .7475 | .881 | .8133 | .888 | .3663 | .4686 | .085 | .014 | .6025 | .5110 | .174 | .018 | .49 |

TABLE IV. (*continued*).

| Given Ratio: Temperature, Pressure, or Volume. | Inverse Ratio. | Ratio of Mean to Initial Total Pressure, for given Ratio of Volumes. | | | | | | Ratio of Total Pressure at Point of Cut-off to Portion of Ratio of Mean Total Pressure during whole Stroke that is due to Expansion, for given Ratio of Volumes. | | | Ratio of Initial and Final Temperatures: Absolute Temperature for Air; Temperature on Fahrenheit's Scale + 100° for Steam. | | | | Ratio of Initial and Final Absolute Pressures. | | | | Ratio of Initial and Final Volumes. | | | | Given Ratio: Temperature, Pressure, or Volume. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | During whole Stroke (supposing Initial Pressure and Pressure at Point of Cut-off to be identical). | | | During Expansion only. | | | | | | For given Ratio of Volumes. | | For given Ratio of Absolute Pressures. | | For given Ratio of Volumes. | | For given Ratio of Temperatures: Absolute Temperature for Air; Temperature on Fahrenheit's Scale + 100° for Steam. | | For given Ratio of Absolute Pressures. | | For given Ratio of Temperatures: Absolute Temperature for Air; Temperature on Fahrenheit's Scale + 100° for Steam. | | |
| | | Perfect Gas, Temperature Constant. | Air expanding without Loss or Gain of Heat. | Saturated Steam. | Perfect Gas, Temperature Constant. | Air expanding without Loss or Gain of Heat. | Saturated Steam. | Perfect Gas, Temperature Constant. | Air expanding without Loss or Gain of Heat. | Saturated Steam. | Air expanding without Loss or Gain of Heat. | Saturated Steam. | Air expanding without Loss or Gain of Heat. | Saturated Steam. | Air expanding without Loss or Gain of Heat. | Saturated Steam. | Air expanding without Loss or Gain of Heat. | Saturated Steam. | Air expanding without Loss or Gain of Heat. | Saturated Steam. | Air expanding without Loss or Gain of Heat. | Saturated Steam. | |
| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 |
| .50 | 2 | .8466 | .8019 | .8392 | .6932 | .6038 | .6784 | .3466 | .3019 | .3392 | .7537 | .884 | .8180 | .891 | .3768 | .4788 | .091 | .016 | .6112 | .5208 | .183 | .020 | .50 |
| .51 | 1.961 | .8534 | .8103 | .8463 | .7008 | .6128 | .6863 | .3434 | .3003 | .3363 | .7598 | .888 | .8227 | .894 | .3875 | .4890 | .098 | .018 | .6199 | .5306 | .192 | .022 | .51 |
| .52 | 1.923 | .8600 | .8185 | .8532 | .7084 | .6218 | .6941 | .3400 | .2985 | .3332 | .7658 | .891 | .8274 | .897 | .3982 | .4992 | .105 | .020 | .6285 | .5404 | .201 | .025 | .52 |
| .53 | 1.887 | .8665 | .8264 | .8599 | .7159 | .6307 | .7019 | .3365 | .2964 | .3299 | .7718 | .894 | .8320 | .900 | .4091 | .5094 | .112 | .022 | .6371 | .5502 | .211 | .028 | .53 |
| .54 | 1.852 | .8727 | .8342 | .8664 | .7234 | .6396 | .7096 | .3327 | .2942 | .3264 | .7777 | .897 | .8365 | .902 | .4200 | .5196 | .119 | .025 | .6456 | .5599 | .221 | .031 | .54 |
| .55 | 1.818 | .8788 | .8418 | .8727 | .7307 | .6484 | .7172 | .3288 | .2918 | .3227 | .7836 | .900 | .8409 | .905 | .4310 | .5298 | .127 | .028 | .6540 | .5697 | .231 | .034 | .55 |
| .56 | 1.786 | .8847 | .8192 | .8789 | .7380 | .6572 | .7247 | .3247 | .2892 | .3189 | .7893 | .902 | .8453 | .908 | .4420 | .5401 | .135 | .031 | .6625 | .5794 | .241 | .038 | .56 |
| .57 | 1.754 | .8904 | .8563 | .8848 | .7451 | .6659 | .7322 | .3204 | .2863 | .3148 | .7951 | .905 | .8497 | .911 | .4532 | .5503 | .144 | .034 | .6708 | .5892 | .252 | .042 | .57 |
| .58 | 1.724 | .8959 | .8633 | .8906 | .7522 | .6745 | .7396 | .3159 | .2833 | .3106 | .8007 | .908 | .8540 | .913 | .4644 | .5606 | .153 | .038 | .6792 | .5989 | .263 | .046 | .58 |
| .59 | 1.695 | .9013 | .8701 | .8962 | .7593 | .6831 | .7469 | .3113 | .2801 | .3062 | .8063 | .911 | .8582 | .916 | .4757 | .5709 | .162 | .042 | .6875 | .6086 | .274 | .051 | .59 |
| .60 | 1.667 | .9065 | .8767 | .9017 | .7662 | .6917 | .7541 | .3065 | .2767 | .3017 | .8119 | .914 | .8624 | .918 | .4871 | .5812 | .172 | .047 | .6957 | .6183 | .286 | .056 | .60 |
| .61 | 1.639 | .9115 | .8831 | .9069 | .7731 | .7002 | .7613 | .3015 | .2731 | .2969 | .8174 | .916 | .8666 | .921 | .4986 | .5914 | .182 | .052 | .7039 | .6280 | .298 | .061 | .61 |
| .62 | 1.613 | .9164 | .8893 | .9120 | .7800 | .7086 | .7684 | .2964 | .2693 | .2920 | .8228 | .919 | .8706 | .923 | .5101 | .6018 | .192 | .057 | .7121 | .6377 | .310 | .067 | .62 |
| .63 | 1.587 | .9211 | .8953 | .9169 | .7867 | .7170 | .7755 | .2911 | .2653 | .2869 | .8282 | .921 | .8747 | .926 | .5218 | .6121 | .203 | .063 | .7203 | .6474 | .322 | .074 | .63 |
| .64 | 1.563 | .9256 | .9011 | .9217 | .7934 | .7254 | .7824 | .2856 | .2611 | .2817 | .8335 | .924 | .8787 | .928 | .5335 | .6224 | .214 | .069 | .7284 | .6570 | .335 | .080 | .64 |
| .65 | 1.538 | .9300 | .9068 | .9263 | .8000 | .7337 | .7894 | .2800 | .2568 | .2763 | .8388 | .927 | .8827 | .931 | .5452 | .6327 | .226 | .075 | .7364 | .6667 | .348 | .088 | .65 |
| .66 | 1.515 | .9342 | .9123 | .9307 | .8066 | .7419 | .7962 | .2742 | .2523 | .2707 | .8441 | .929 | .8866 | .933 | .5571 | .6431 | .238 | .083 | .7445 | .6763 | .361 | .096 | .66 |
| .67 | 1.493 | .9383 | .9176 | .9350 | .8131 | .7501 | .8030 | .2683 | .2475 | .2650 | .8493 | .932 | .8904 | .935 | .5690 | .6534 | .251 | .090 | .7524 | .6860 | .375 | .104 | .67 |
| .68 | 1.471 | .9423 | .9227 | .9391 | .8196 | .7583 | .8097 | .2623 | .2427 | .2591 | .8544 | .934 | .8943 | .938 | .5810 | .6638 | .264 | .099 | .7604 | .6956 | .389 | .113 | .68 |
| .69 | 1.449 | .9460 | .9276 | .9431 | .8259 | .7664 | .8164 | .2560 | .2376 | .2531 | .8595 | .936 | .8981 | .940 | .5931 | .6742 | .278 | .108 | .7683 | .7052 | .403 | .123 | .69 |
| .70 | 1.429 | .9497 | .9324 | .9469 | .8322 | .7745 | .8230 | .2497 | .2324 | .2469 | .8646 | .939 | .9018 | .942 | .6052 | .6846 | .292 | .118 | .7762 | .7148 | .417 | .133 | .70 |
| .71 | 1.408 | .9532 | .9369 | .9506 | .8385 | .7826 | .8296 | .2432 | .2269 | .2406 | .8696 | .941 | .9055 | .945 | .6174 | .6950 | .307 | .128 | .7841 | .7245 | .432 | .145 | .71 |
| .72 | 1.389 | .9565 | .9414 | .9541 | .8447 | .7906 | .8361 | .2365 | .2214 | .2341 | .8746 | .943 | .9092 | .947 | .6297 | .7054 | .322 | .139 | .7919 | .7341 | .447 | .156 | .72 |
| .73 | 1.370 | .9597 | .9456 | .9575 | .8509 | .7985 | .8426 | .2297 | .2156 | .2275 | .8795 | .946 | .9128 | .949 | .6420 | .7158 | .338 | .151 | .7997 | .7436 | .462 | .169 | .73 |
| .74 | 1.351 | .9628 | .9497 | .9607 | .8570 | .8064 | .8490 | .2228 | .2097 | .2207 | .8844 | .948 | .9165 | .951 | .6545 | .7262 | .354 | .164 | .8075 | .7532 | .478 | .183 | .74 |

TABLE IV. (*continued*).

| GIVEN RATIO: TEMPERATURE, PRESSURE, OR VOLUME. | Inverse Ratio. | Ratio of Mean to Initial Total Pressure, for given Ratio of Volumes. | | | | | | Ratio of Total Pressure at Point of Cut-off to Portion of Ratio of Mean Total Pressure during whole Stroke that is due to Expansion, for given Ratio of Volumes. | | | Ratio of Initial and Final Temperatures: Absolute Temperature for Air; Temperature on Fahrenheit's Scale + 100° for Steam. | | | | Ratio of Initial and Final Absolute Pressures. | | | | Ratio of Initial and Final Volumes. | | | | GIVEN RATIO: TEMPERATURE, PRESSURE, OR VOLUME. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | During whole Stroke (supposing Initial Pressure and Pressure at Point of Cut-off to be identical). | | | During Expansion only. | | | | | | For given Ratio of Volumes. | | For given Ratio of Absolute Pressures. | | For given Ratio of Volumes. | | For given Ratio of Temperatures: Absolute Temperature for Air; Temperature on Fahrenheit's Scale + 100° for Steam. | | For given Ratio of Absolute Pressures. | | For given Ratio of Temperatures: Absolute Temperature for Air; Temperature on Fahrenheit's Scale + 100° for Steam. | | |
| | | Perfect Gas, Temperature Constant. | Air expanding without Loss or Gain of Heat. | Saturated Steam. | Perfect Gas, Temperature Constant. | Air expanding without Loss or Gain of Heat. | Saturated Steam. | Perfect Gas, Temperature Constant. | Air expanding without Loss or Gain of Heat. | Saturated Steam. | Air expanding without Loss or Gain of Heat. | Saturated Steam. | Air expanding without Loss or Gain of Heat. | Saturated Steam. | Air expanding without Loss or Gain of Heat. | Saturated Steam. | Air expanding without Loss or Gain of Heat. | Saturated Steam. | Air expanding without Loss or Gain of Heat. | Saturated Steam. | Air expanding without Loss or Gain of Heat. | Saturated Steam. | |
| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 |
| .75 | 1.333 | .9658 | .9536 | .9638 | .8631 | .8143 | .8553 | .2158 | .2036 | .2138 | .8893 | .950 | .9200 | .953 | .6669 | .7366 | .371 | .178 | .8152 | .7628 | .494 | .197 | .75 |
| .76 | 1.316 | .9686 | .9573 | .9668 | .8691 | .8221 | .8616 | .2086 | .1973 | .2068 | .8941 | .953 | .9236 | .955 | .6795 | .7471 | .388 | .193 | .8229 | .7724 | .510 | .212 | .76 |
| .77 | 1.299 | .9713 | .9609 | .9696 | .8750 | .8300 | .8679 | .2013 | .1909 | .1996 | .8989 | .955 | .9271 | .957 | .6921 | .7575 | .406 | .208 | .8306 | .7819 | .527 | .229 | .77 |
| .78 | 1.282 | .9738 | .9643 | .9723 | .8809 | .8377 | .8741 | .1938 | .1843 | .1923 | .9036 | .957 | .9305 | .959 | .7048 | .7680 | .424 | .225 | .8382 | .7915 | .544 | .246 | .78 |
| .79 | 1.266 | .9762 | .9675 | .9749 | .8868 | .8455 | .8803 | .1862 | .1776 | .1849 | .9083 | .959 | .9340 | .961 | .7176 | .7785 | .443 | .243 | .8459 | .8010 | .561 | .264 | .79 |
| .80 | 1.25 | .9785 | .9706 | .9773 | .8926 | .8532 | .8864 | .1785 | .1706 | .1773 | .9130 | .961 | .9374 | .963 | .7304 | .7889 | .463 | .262 | .8534 | .8106 | .579 | .283 | .80 |
| .81 | 1.235 | .9807 | .9736 | .9796 | .8983 | .8608 | .8925 | .1707 | .1636 | .1696 | .9176 | .963 | .9408 | .965 | .7433 | .7994 | .483 | .282 | .8610 | .8201 | .597 | .304 | .81 |
| .82 | 1.22 | .9827 | .9763 | .9817 | .9041 | .8684 | .8985 | .1627 | .1563 | .1617 | .9222 | .965 | .9441 | .967 | .7562 | .8099 | .504 | .304 | .8685 | .8296 | .615 | .326 | .82 |
| .83 | 1.205 | .9847 | .9789 | .9838 | .9097 | .8760 | .9045 | .1547 | .1489 | .1538 | .9268 | .968 | .9474 | .969 | .7692 | .8204 | .526 | .327 | .8761 | .8392 | .633 | .349 | .83 |
| .84 | 1.19 | .9865 | .9814 | .9857 | .9154 | .8836 | .9104 | .1465 | .1414 | .1457 | .9313 | .970 | .9507 | .971 | .7823 | .8309 | .548 | .351 | .8835 | .8487 | .652 | .374 | .84 |
| .85 | 1.176 | .9881 | .9837 | .9874 | .9209 | .8911 | .9162 | .1381 | .1337 | .1374 | .9358 | .972 | .9540 | .973 | .7955 | .8414 | .571 | .377 | .8910 | .8582 | .671 | .399 | .85 |
| .86 | 1.163 | .9897 | .9858 | .9891 | .9265 | .8986 | .9221 | .1297 | .1258 | .1291 | .9403 | .974 | .9572 | .975 | .8087 | .8519 | .594 | .405 | .8984 | .8678 | .691 | .427 | .86 |
| .87 | 1.119 | .9912 | .9878 | .9906 | .9320 | .9060 | .9279 | .1212 | .1178 | .1206 | .9448 | .976 | .9605 | .977 | .8220 | .8625 | .618 | .434 | .9058 | .8772 | .711 | .455 | .87 |
| .88 | 1.136 | .9925 | .9896 | .9920 | .9375 | .9134 | .9337 | .1125 | .1096 | .1120 | .9492 | .978 | .9636 | .979 | .8353 | .8730 | .643 | .464 | .9132 | .8666 | .731 | .486 | .88 |
| .89 | 1.124 | .9937 | .9913 | .9933 | .9429 | .9208 | .9394 | .1037 | .1013 | .1033 | .9536 | .980 | .9668 | .981 | .8487 | .8835 | .669 | .497 | .9206 | .8961 | .752 | .518 | .89 |
| .90 | 1.111 | .9948 | .9928 | .9945 | .9482 | .9282 | .9451 | .0948 | .0928 | .0945 | .9579 | .982 | .9699 | .983 | .8621 | .8941 | .695 | .531 | .9279 | .9056 | .772 | .552 | .90 |
| .91 | 1.099 | .9958 | .9942 | .9956 | .9536 | .9355 | .9508 | .0858 | .0842 | .0856 | .9623 | .983 | .9730 | .984 | .8757 | .9047 | .722 | .568 | .9352 | .9151 | .794 | .587 | .91 |
| .92 | 1.087 | .9967 | .9954 | .9965 | .9589 | .9428 | .9564 | .0767 | .0754 | .0765 | .9666 | .985 | .9761 | .986 | .8892 | .9152 | .750 | .606 | .9425 | .9245 | .815 | .624 | .92 |
| .93 | 1.075 | .9975 | .9965 | .9973 | .9642 | .9500 | .9620 | .0675 | .0665 | .0673 | .9708 | .987 | .9792 | .988 | .9029 | .9258 | .778 | .647 | .9498 | .9340 | .837 | .664 | .93 |
| .94 | 1.064 | .9982 | .9974 | .9981 | .9694 | .9572 | .9675 | .0582 | .0574 | .0581 | .9751 | .989 | .9822 | .990 | .9166 | .9364 | .808 | .690 | .9570 | .9434 | .859 | .705 | .94 |
| .95 | 1.053 | .9987 | .9982 | .9987 | .9746 | .9645 | .9730 | .0487 | .0482 | .0487 | .9793 | .991 | .9853 | .991 | .9303 | .9470 | .838 | .735 | .9642 | .9529 | .882 | .749 | .95 |
| .96 | 1.042 | .9992 | .9989 | .9991 | .9797 | .9716 | .9785 | .0392 | .0389 | .0391 | .9835 | .993 | .9882 | .993 | .9441 | .9576 | .869 | .783 | .9714 | .9623 | .905 | .794 | .96 |
| .97 | 1.031 | .9996 | .9994 | .9995 | .9849 | .9788 | .9840 | .0296 | .0294 | .0295 | .9877 | .995 | .9912 | .995 | .9580 | .9682 | .900 | .833 | .9786 | .9717 | .928 | .842 | .97 |
| .98 | 1.02 | .9998 | .9997 | .9998 | .9899 | .9859 | .9895 | .0198 | .0197 | .0198 | .9918 | .996 | .9942 | .997 | .9720 | .9788 | .933 | .886 | .9858 | .9812 | .952 | .892 | .98 |
| .99 | 1.01 | .9999 | .9999 | .9999 | .9950 | .9929 | .9947 | .0099 | .0099 | .0099 | .9959 | .998 | .9971 | .998 | .9860 | .9894 | .966 | .941 | .9929 | .9906 | .976 | .945 | .99 |

The following formulas for the weight and volume of air at different temperatures will facilitate the calculation of these data for any case that may arise in practice: A cubic foot of dry air, at atmospheric pressure and any absolute temperature ($=$ temperature on Fahrenheit's scale $+ 461.2°$) $T$, weighs $\frac{39.819}{T}$ lbs., and the volume of a pound is $\frac{T}{39.819}$ cubic feet. Some results of the above formulas are given in the next table.

Table V., *showing Weight and Volume of Dry Air at Atmospheric Pressure.*

| Temperature, Fahrenheit Scale, Degrees. | Weight of a Cubic Foot, in Pounds. | Volume of a Pound, in Cubic Feet. | Temperature, Fahrenheit Scale, Degrees. | Weight of a Cubic Foot, in Pounds. | Volume of a Pound, in Cubic Feet. | Temperature, Fahrenheit Scale, Degrees. | Weight of a Cubic Foot, in Pounds. | Volume of a Pound, in Cubic Feet. |
|---|---|---|---|---|---|---|---|---|
| 0 | .0863 | 11.582 | 70 | .0750 | 12.340 | 150 | .0651 | 15.350 |
| 10 | .0845 | 11.834 | 80 | .0736 | 13.592 | 160 | .0641 | 15.601 |
| 20 | .0827 | 12.085 | 90 | .0722 | 13.843 | 170 | .0631 | 15.852 |
| 30 | .0811 | 12.336 | 100 | .0710 | 14.094 | 180 | .0621 | 16.103 |
| 32 | .0807 | 12.386 | 110 | .0697 | 14.345 | 190 | .0611 | 16.354 |
| 40 | .0794 | 12.587 | 120 | .0685 | 14.596 | 200 | .0602 | 16.605 |
| 50 | .0779 | 12.838 | 130 | .0674 | 14.847 | 210 | .0593 | 16.856 |
| 60 | .0764 | 13.089 | 140 | .0662 | 15.098 | 212 | .0591 | 16.907 |

If the temperature and pressure of the air both vary, the weight of a cubic foot of dry air, at absolute pressure $P$ (in pounds per square inch) and absolute temperature $T$, is $\frac{2.7093 \times P}{T}$ lbs.; and the volume of a pound is $\frac{T}{2.7093 \times P}$ cubic feet. If the temperature of air is changed from one absolute temperature $T$ to another absolute temperature $t$, the volume remaining constant, the pressure is changed from $P$ to $\frac{P \times T}{t}$.

When expansion takes place in the cylinder of an engine, the real ratio of expansion cannot be ascertained by dividing the space passed over by the piston before expansion by the total space traversed, since expansion also takes place in the clearance space of the cylinder, which is made up of the piston clearance and the port area; but table VI. gives the real cut-off corresponding to the apparent cut-off, for most fractions of clearance that obtain in practice. If $\frac{1}{r}$ is the apparent cut-off, and $c$ the fraction of clearance, the real cut-off is $\frac{\frac{1}{r} + c}{1 + c}$; which formula was employed in the calculation of the table, and can be used for fractions of clearance beyond the range of the table.

*Examples.*—1. It is required to find the mean pressure of air expanding without gain or loss of heat, the initial pressure being 60 lbs. above zero, and the final pressure 15 lbs. per square inch; also the ratio of expansion, the pressures at five points taken at intervals during the expansion, and the final temperature, that at the beginning being 350° F. $15 \div 60 = 0.25$; and the number in column 7 of table IV. corresponding to 0.25 in column 1 is 0.3529; hence the mean pressure during expansion $= 60 \times 0.3529 = 21.174$ lbs. per square inch. From column 20 of the same table it appears that the required ratio of expansion is $1 \div 0.3736 = 2.6767$. This ratio of expansion corresponds to a cut-off of 0.37 of the stroke, so that the ratios of initial volume to volumes at the several points of division are respectively 0.75, 0.60, 0.50, 0.43, and 0.37;* and the pressures at these several points are (according to column 16):

| | |
|---|---|
| At commencement of expansion.............................. | $60 \times 1 = 60$ |
| At first point of division.................................. | $60 \times 0.67 = 40.2$ |
| At second point of division............................... | $60 \times 0.49 = 29.4$ |
| At third point of division................................. | $60 \times 0.38 = 22.8$ |
| At fourth point of division ............................... | $60 \times 0.30 = 18$ |
| At end of expansion........................................ | $60 \times 0.25 = 15$ |

The initial absolute temperature being $350° + 461.2° = 811.2°$, the final absolute temperature by column $12 = 811.2° \times 0.667 = 541.1°$, and the corresponding temperature on Fahrenheit's scale $= 541.1° - 461.2° = 79.9°$.

2. If air having a temperature of 70° F., and a pressure of 20 lbs. per square inch above zero, is compressed without loss or gain of heat to 90 lbs., what is the final temperature? $90 \div 20 = 0.45$;

* These numbers are obtained as follows: Calling the final volume 1, the volume when expansion commences is 0.37, and the volume during expansion is $1 - 0.37 = 0.63$. Dividing this volume into five equal parts, each part $= 0.63 \div 5 = 0.126$, and the ratios of initial volume to volume at the several points of division are $\frac{0.37}{0.37 + 0.126} = 0.75$, $\frac{0.37}{0.37 + 0.126 \times 2} = 0.60$, etc.

TABLE VI., *showing Real Cut-off, corresponding to Apparent Cut-off, for Different Fractions of Clearance.*

| APPARENT CUT-OFF. | REAL CUT-OFF, FOR FRACTION OF CLEARANCE OF .01 | .02 | .03 | .04 | .05 | .06 | .07 | .08 | .09 | .1 |
|---|---|---|---|---|---|---|---|---|---|---|
| .01 | .020 | .030 | .039 | .048 | .057 | .066 | .075 | .083 | .092 | .100 |
| .02 | .030 | .040 | .049 | .058 | .067 | .075 | .084 | .092 | .101 | .109 |
| .03 | .040 | .050 | .058 | .067 | .076 | .085 | .093 | .101 | .110 | .118 |
| .04 | .050 | .059 | .068 | .077 | .086 | .094 | .103 | .111 | .119 | .127 |
| .05 | .060 | .069 | .078 | .087 | .095 | .104 | .112 | .120 | .128 | .136 |
| .06 | .070 | .079 | .087 | .096 | .105 | .113 | .121 | .129 | .137 | .145 |
| .07 | .080 | .088 | .097 | .106 | .114 | .122 | .131 | .139 | .146 | .154 |
| .08 | .090 | .098 | .106 | .115 | .124 | .132 | .140 | .148 | .155 | .163 |
| .09 | .100 | .108 | .116 | .125 | .133 | .141 | .149 | .157 | .164 | .172 |
| .10 | .109 | .118 | .126 | .135 | .143 | .151 | .159 | .167 | .174 | .182 |
| .11 | .119 | .128 | .136 | .145 | .153 | .160 | .168 | .177 | .183 | .191 |
| .12 | .129 | .138 | .146 | .154 | .162 | .170 | .177 | .185 | .192 | .200 |
| .13 | .139 | .148 | .155 | .164 | .172 | .179 | .187 | .194 | .201 | .209 |
| .14 | .149 | .158 | .165 | .174 | .181 | .189 | .196 | .204 | .211 | .218 |
| .15 | .159 | .167 | .175 | .183 | .191 | .198 | .205 | .213 | .220 | .227 |
| .16 | .169 | .177 | .184 | .193 | .200 | .207 | .215 | .222 | .229 | .236 |
| .17 | .179 | .187 | .194 | .202 | .210 | .217 | .224 | .231 | .238 | .245 |
| .18 | .189 | .197 | .204 | .212 | .219 | .226 | .233 | .240 | .247 | .254 |
| .19 | .199 | .207 | .214 | .222 | .229 | .236 | .243 | .250 | .257 | .264 |
| .20 | .208 | .216 | .223 | .231 | .238 | .245 | .252 | .259 | .266 | .273 |
| .21 | .218 | .226 | .233 | .241 | .248 | .255 | .261 | .268 | .275 | .282 |
| .22 | .228 | .236 | .243 | .251 | .257 | .264 | .271 | .277 | .284 | .291 |
| .23 | .238 | .246 | .252 | .260 | .267 | .274 | .280 | .287 | .293 | .300 |
| .24 | .248 | .256 | .262 | .270 | .276 | .283 | .290 | .296 | .303 | .309 |
| .25 | .258 | .265 | .272 | .279 | .286 | .293 | .299 | .305 | .312 | .318 |
| .26 | .268 | .275 | .281 | .289 | .295 | .302 | .308 | .315 | .321 | .327 |
| .27 | .278 | .285 | .291 | .298 | .305 | .312 | .318 | .324 | .330 | .336 |
| .28 | .288 | .295 | .301 | .308 | .314 | .321 | .327 | .333 | .339 | .345 |
| .29 | .298 | .305 | .311 | .318 | .324 | .331 | .337 | .343 | .349 | .355 |
| .30 | .307 | .314 | .320 | .327 | .333 | .340 | .346 | .352 | .358 | .364 |
| .31 | .317 | .324 | .330 | .337 | .343 | .349 | .355 | .361 | .367 | .373 |
| .32 | .327 | .334 | .340 | .346 | .352 | .359 | .364 | .370 | .376 | .382 |
| .33 | .337 | .344 | .349 | .356 | .362 | .368 | .374 | .379 | .385 | .391 |
| .34 | .347 | .354 | .359 | .366 | .371 | .378 | .383 | .389 | .395 | .400 |
| .35 | .357 | .363 | .369 | .375 | .381 | .387 | .392 | .398 | .404 | .409 |
| .36 | .367 | .373 | .378 | .385 | .390 | .396 | .402 | .407 | .413 | .418 |
| .37 | .377 | .383 | .388 | .394 | .400 | .406 | .411 | .416 | .422 | .427 |
| .38 | .387 | .393 | .398 | .404 | .409 | .415 | .420 | .425 | .431 | .436 |
| .39 | .396 | .403 | .408 | .414 | .419 | .425 | .430 | .435 | .441 | .446 |
| .40 | .406 | .412 | .417 | .423 | .429 | .434 | .439 | .444 | .450 | .455 |
| .41 | .416 | .422 | .427 | .433 | .439 | .443 | .448 | .453 | .459 | .464 |
| .42 | .426 | .432 | .437 | .442 | .448 | .453 | .458 | .462 | .468 | .473 |
| .43 | .436 | .442 | .446 | .452 | .458 | .462 | .467 | .472 | .477 | .482 |
| .44 | .446 | .452 | .456 | .462 | .467 | .472 | .477 | .481 | .486 | .491 |
| .45 | .456 | .461 | .466 | .471 | .477 | .481 | .486 | .490 | .495 | .500 |
| .46 | .465 | .471 | .475 | .481 | .486 | .490 | .495 | .500 | .504 | .509 |
| .47 | .475 | .481 | .485 | .490 | .496 | .500 | .505 | .509 | .513 | .518 |
| .48 | .485 | .491 | .495 | .500 | .505 | .509 | .514 | .518 | .522 | .527 |
| .49 | .495 | .501 | .505 | .510 | .515 | .519 | .524 | .528 | .532 | .537 |
| .50 | .505 | .510 | .514 | .519 | .524 | .528 | .533 | .537 | .541 | .546 |

| APPARENT CUT-OFF. | REAL CUT-OFF, FOR FRACTION OF CLEARANCE OF .01 | .02 | .03 | .04 | .05 | .06 | .07 | .08 | .09 | .1 |
|---|---|---|---|---|---|---|---|---|---|---|
| .51 | .515 | .520 | .524 | .529 | .534 | .538 | .542 | .546 | .550 | .555 |
| .52 | .525 | .530 | .534 | .538 | .543 | .547 | .551 | .555 | .559 | .564 |
| .53 | .535 | .540 | .544 | .548 | .553 | .557 | .561 | .565 | .568 | .573 |
| .54 | .545 | .550 | .554 | .558 | .562 | .566 | .570 | .574 | .578 | .582 |
| .55 | .554 | .559 | .563 | .567 | .572 | .576 | .579 | .583 | .587 | .591 |
| .56 | .564 | .569 | .573 | .577 | .581 | .585 | .589 | .593 | .596 | .600 |
| .57 | .574 | .579 | .583 | .586 | .591 | .595 | .598 | .602 | .605 | .609 |
| .58 | .584 | .589 | .593 | .596 | .600 | .604 | .607 | .611 | .614 | .618 |
| .59 | .594 | .599 | .603 | .606 | .610 | .614 | .617 | .621 | .624 | .628 |
| .60 | .604 | .608 | .612 | .615 | .619 | .623 | .626 | .630 | .633 | .637 |
| .61 | .614 | .618 | .622 | .625 | .629 | .632 | .635 | .639 | .642 | .646 |
| .62 | .624 | .628 | .632 | .634 | .638 | .642 | .645 | .648 | .651 | .655 |
| .63 | .634 | .638 | .641 | .644 | .648 | .651 | .654 | .657 | .660 | .664 |
| .64 | .644 | .648 | .651 | .654 | .657 | .661 | .664 | .667 | .670 | .673 |
| .65 | .654 | .657 | .661 | .663 | .667 | .670 | .673 | .676 | .679 | .682 |
| .66 | .664 | .667 | .670 | .673 | .676 | .679 | .682 | .685 | .688 | .691 |
| .67 | .673 | .677 | .680 | .682 | .686 | .689 | .692 | .694 | .697 | .700 |
| .68 | .683 | .687 | .690 | .692 | .695 | .698 | .701 | .703 | .706 | .709 |
| .69 | .693 | .697 | .700 | .702 | .705 | .708 | .711 | .713 | .716 | .718 |
| .70 | .703 | .706 | .709 | .711 | .714 | .717 | .720 | .722 | .725 | .727 |
| .71 | .713 | .716 | .719 | .721 | .724 | .726 | .729 | .731 | .734 | .736 |
| .72 | .723 | .726 | .729 | .731 | .733 | .736 | .738 | .740 | .743 | .745 |
| .73 | .733 | .736 | .738 | .740 | .743 | .745 | .748 | .750 | .752 | .754 |
| .74 | .743 | .746 | .748 | .750 | .752 | .755 | .757 | .759 | .762 | .763 |
| .75 | .753 | .755 | .758 | .760 | .762 | .764 | .766 | .768 | .771 | .772 |
| .76 | .763 | .765 | .767 | .769 | .771 | .773 | .776 | .778 | .780 | .781 |
| .77 | .772 | .775 | .777 | .779 | .781 | .783 | .785 | .787 | .789 | .790 |
| .78 | .782 | .785 | .787 | .789 | .790 | .792 | .794 | .796 | .798 | .799 |
| .79 | .792 | .795 | .797 | .799 | .800 | .802 | .804 | .806 | .808 | .809 |
| .80 | .802 | .804 | .806 | .808 | .809 | .811 | .813 | .815 | .817 | .818 |
| .81 | .812 | .814 | .816 | .818 | .819 | .821 | .822 | .824 | .826 | .827 |
| .82 | .822 | .824 | .826 | .827 | .828 | .830 | .832 | .833 | .835 | .836 |
| .83 | .832 | .834 | .835 | .837 | .838 | .840 | .841 | .842 | .844 | .845 |
| .84 | .842 | .844 | .845 | .847 | .848 | .849 | .851 | .852 | .853 | .854 |
| .85 | .852 | .853 | .855 | .856 | .857 | .859 | .860 | .861 | .862 | .863 |
| .86 | .862 | .863 | .864 | .866 | .867 | .868 | .869 | .870 | .871 | .872 |
| .87 | .871 | .873 | .874 | .875 | .876 | .878 | .879 | .879 | .880 | .881 |
| .88 | .881 | .883 | .884 | .885 | .886 | .887 | .888 | .888 | .889 | .890 |
| .89 | .891 | .893 | .894 | .895 | .896 | .897 | .898 | .898 | .899 | .900 |
| .90 | .901 | .902 | .903 | .904 | .905 | .906 | .907 | .907 | .908 | .909 |
| .91 | .911 | .912 | .913 | .914 | .915 | .915 | .916 | .916 | .917 | .918 |
| .92 | .921 | .922 | .923 | .923 | .924 | .925 | .925 | .925 | .926 | .927 |
| .93 | .931 | .932 | .932 | .933 | .934 | .934 | .935 | .935 | .935 | .936 |
| .94 | .941 | .942 | .942 | .943 | .943 | .944 | .944 | .944 | .945 | .945 |
| .95 | .950 | .951 | .952 | .952 | .953 | .953 | .953 | .953 | .954 | .954 |
| .96 | .960 | .961 | .961 | .962 | .962 | .962 | .963 | .963 | .963 | .963 |
| .97 | .970 | .971 | .971 | .972 | .972 | .972 | .972 | .972 | .972 | .972 |
| .98 | .980 | .981 | .981 | .981 | .981 | .981 | .981 | .981 | .981 | .981 |
| .99 | .990 | .991 | .991 | .991 | .991 | .991 | .991 | .991 | .991 | .991 |

hence, according to column 14 in table IV., the final temperature on Fahrenheit's scale $= (70° + 461.2°) \div 0.793 - 461.2° = 208.7°$.

3. Find, from column 15 in table IV., the approximate temperature of steam at a pressure of 80 lbs. per square inch above zero. The temperature of steam at atmospheric pressure (14.7 lbs. per square inch) being 212°, the ratio of pressures $= 14.7 \div 80 = 0.18$; so that the approximate temperature $= (212° + 100°) \div 0.751 - 100° = 315°$.

4. If steam is cut off in a cylinder at quarter stroke, and expands without condensation, what is the mean total pressure, the initial pressure being 80 lbs. per square inch above zero? According to column 5 in table IV., the mean total pressure $= 80 \times 0.58 = 46.4$ lbs. per square inch.

5. The theoretical curve of expansion in the case of steam-engines is commonly assumed to be a hyperbola with rectangular asymptotes; in making which assumption, it is supposed that the steam in its expansion conforms to the law of a perfect gas, expanding at constant temperature. Although this assumption is not strictly true, no serious error arises from its use in ordinary cases, and it is very convenient when calculations are to be made without the aid of tables.

For other applications of the tables in this article, see ENGINES, DESIGNING OF. R. H. B.

EXPLOSIVES. It is convenient to divide explosive agents into *explosive compounds* and *explosive mixtures*. In an explosive compound, the elements composing it are in chemical combination, and cannot be separated except by chemical change. In an explosive mixture, the ingredients are mechanically mixed, and can be separated by mechanical means. In an explosive mixture, properly so called, the separate constituents do not have explosive properties, but these belong to the mixture only. For instance, gunpowder is an explosive mixture, but dynamite is not, for it is merely the explosive compound nitro-glycerine, contained in an inert absorbent which has no explosive properties. While this distinction is a good one in the main, it is not always strictly applicable. There are some mixtures which contain substances having themselves explosive properties. In such a case, however, the explosive properties of the compound are not sufficiently great to render it useful by itself, and it enters into the mixture as a combustible ingredient. Thus, a picrate has a certain quantity of oxygen available in the explosive reaction, but not enough, so it is mixed with a substance supplying oxygen, such as potassium nitrate (saltpetre) or potassium chlorate.

There are a great number of compounds known to possess explosive properties, but only a very few are used in practice. In his "Notes on Explosives," Prof. W. N. Hill, of the United States torpedo station, Newport, R. I., describes nitro-glycerine and its preparations, gun-cotton and its preparations, the picrates (including, for convenience, some *mixtures* containing picrates), and the fulminates; afterward reference is made to gunpowder.

EXPLOSIVE COMPOUNDS.—*Nitro-glycerine* is formed by the action of nitric acid upon glycerine at a low temperature. The process of manufacture consists essentially in the slow mixing of the glycerine with the acid, a low temperature being preserved during the whole operation, and in separating and washing the nitro-glycerine from the excess of acid with water. The glycerine is the commercial article of good quality. It must be free from the adulterations often found in it. The nitric acid must be strong, having a specific gravity of not less than 1.45. Nitric acid of this strength cannot be obtained in the market, and must therefore be specially prepared for the purpose. This is done by careful distillation from sodium nitrate (Chili saltpetre) and sulphuric acid (oil of vitriol). Before it is used the nitric acid is mixed with twice its weight of strong sulphuric acid. The latter does not take a direct part in the production of the nitro-glycerine, but takes up the water which is formed during the reaction, thereby preventing the dilution of the nitric acid. The sulphuric and nitric acids, mixed in the proper proportions (one of nitric to two of sulphuric), are placed in a large stoneware receiver, from which the mixture can be drawn as it is required.

At ordinary temperatures nitro-glycerine is an oily liquid, having a specific gravity of 1.6. Freshly made, it is creamy-white and opaque, but becomes transparent ("clears") and colorless, or nearly so, on standing for a sufficient time, depending on the temperature. It does not mix with and is unaffected by water. It has a sweet, pungent, aromatic taste, and produces a violent headache if placed upon the tongue, or even if allowed to touch the skin at any point. Those constantly using it soon lose their susceptibility to this action. Nitro-glycerine freezes to a white crystalline mass at 39° or 40°. When frozen it can be thawed by placing the vessel containing it in water at a temperature not over 100°.

Pure nitro-glycerine does not spontaneously decompose at any ordinary temperature, but if it contains free acid decomposition is apt to occur. It is therefore very important that all acid should be removed by thorough washing when it is made.

If flame is applied to freely-exposed nitro-glycerine, it burns slowly without explosion. The firing-point is about 180° C. (356° F.). It begins to decompose at a somewhat lower temperature. Nitro-glycerine is usually fired by means of a fuse containing fulminating mercury. By such a fuse it is detonated, producing a very violent explosion. Fired with a fuse charged with gunpowder, its action is very uncertain; sometimes it is exploded and sometimes it is not, but when so exploded its explosive force is much less than when the fulminate is used.

Nitro-glycerine may be conveniently kept in large earthen jars, with a layer of water over the explosive. If it is to be transported, the liquid form is very inconvenient, especially from the danger of leakage. It is therefore advisable to freeze it and carry it in the frozen state, when it is perfectly safe. For transportation it should be put in strong tin cans holding about 45 or 50 lbs. Each can should be paraffined on the inside, and have a tin tube passing vertically through its centre, so that freezing or thawing may be more easily accomplished. All vessels in which nitro-glycerine has been kept should be destroyed when not wanted for the same use, as the nitro-glycerine cannot be easily washed off. Nitro-glycerine is the most powerful explosive in use. In difficult blasting, where very violent effects are required, it surpasses all others. It shatters rocks into fine fragments, leaving no residue and giving no smoke. It has been very successfully used in submarine blasting. (See BLASTING.)

Nitro-glycerine Preparations.—The transportation and practical use of nitro-glycerine have been found to be attended with such dangers, that it is now used almost entirely in the shape in which it was first brought before the world—that is, absorbed in some substance which will hold it suspended in its pores, as a sponge will water. Gunpowder and analogous substances were at first used for this purpose; but as these cannot absorb any great quantities of nitro-glycerine, a silicious earth has been largely substituted for them, forming what in this country is known as dynamite.

*Dynamite.*—In dynamite, the absorbent is usually a natural silicious earth. Deposits of this silicious earth are found in many places, notably in Hanover. From the Hanover earth the original dynamite was made. This silicious earth, or "kieselguhr," is a fine white powder, composed of the skeletons of microscopic animals (infusoria). It has a high absorptive power, being capable of taking up from two to three times its weight of nitro-glycerine without becoming pasty.

The process of making dynamite is very simple. The nitro-glycerine is mixed with the dry, fine powder in a leaden vessel with wooden spatulas. Dynamite has a brown color, and resembles in appearance moist brown sugar. It usually contains from 60 to 75 per cent. of nitro-glycerine. In this country dynamite is made and sold under the name of giant powder. The explosive properties of dynamite are those of the nitro-glycerine contained in it, as the absorbent is an inert body. It freezes, at the same temperature as its nitro-glycerine, to a white mass. If solidly frozen, it cannot be fired except by the use of an extra-strong cap; but if loose and pulverulent, it can be exploded, although with diminished violence. It can be thawed by placing the vessel containing it in hot water. The keeping qualities of dynamite are those of the nitro-glycerine it is made from. It is safer, because it avoids the liquid condition, and from its softness it will bear blows much better. Exudation must be guarded against; therefore it must not contain too much nitro-glycerine, especially if it is liable to be exposed to comparatively high temperatures, which tend to make the nitro-glycerine more fluid, and consequently less easily retained. The firing-point of dynamite is the same as its nitro-glycerine. If flame is applied to it, it takes fire and burns with a strong flame, leaving a residue of silica. It is not sensitive to friction or moderate percussion. Dynamite is fired by a fulminate fuse. Gunpowder will fire it, but not with certainty, and the effect obtained is much less than when the stronger agent is employed.

The explosive force of dynamite is, of course, that of the nitro-glycerine contained in it. If it contains 75 per cent., its comparative force may then be approximately stated at six times that of gunpowder. For practical details relative to the use of dynamite, see *Engineering*, xxv., 465.

*Dynamite No. 2.*—Dynamite proper contains only nitro-glycerine and the silicious absorbent. Mixtures containing other substances are sometimes included under the same name. The true dynamite is often called "Dynamite No. 1," and the others "Dynamite No. 2," or receive fanciful names. All these mixtures contain less nitro-glycerine than the No. 1, so that they cost less per pound, but of course they are proportionately less powerful.

*Lithofracteur.*—Lithofracteur is a mixture which has the composition (Trauzl): Nitro-glycerine, 52.10 per cent.; kieselguhr, 30; coal, 12; soda saltpetre, 4; sulphur, 2. Sometimes, instead of the sodium nitrate, the potassium or barium salt is used, and variations are made in the quantity of nitro-glycerine contained in it. Like all the nitro-glycerine preparations, it has no necessarily definite composition, being merely a mixture made according to the caprice of the manufacturers. Lithofracteur must be regarded as inferior to dynamite proper, especially for military purposes. It is much more liable to exudation. The mixtures known in this country as giant-powder No. 2, rendrock, etc., and those already spoken of under the head of dynamite No. 2, are somewhat similar to lithofracteur.

*Dualin* is a mixture made by Carl Dittmar, a Prussian, of nitro-glycerine, sawdust, and saltpetre, in about the proportions: Nitro-glycerine, 50 per cent.; fine sawdust, 30; saltpetre, 20 (Trauzl). This preparation is also inferior to dynamite. The sawdust and saltpetre have much less absorptive power than the silicious earth, and retain the nitro-glycerine comparatively feebly. Its firing-point is said to be considerably lower than that of dynamite No. 1. Also, its lower specific gravity is a drawback.

Dynamite, lithofracteur, and dualin have in great measure been supplanted by mixtures in which the nitro-glycerine is absorbed in an explosive substance, since in this way the whole of the material put into the blast-hole is utilized. These mixtures are substantially the same as those in which nitro-glycerine was first used. They all consist of a pulverized material analogous to gunpowder dust, to which some wood-fibre or saw-dust is added to increase the capacity for absorption of the nitro-glycerine. By the force of the fulminating cap the absorbent body is detonated as well as the nitro-glycerine. Now, since detonated gunpowder has been proved to be much more powerful than fired gunpowder, it will be seen that not only the nitro-glycerine is utilized, but also the gunpowder absorbent to the fullest extent of which it is capable. These powders are known by various trade-names, such as rendrock, Hercules, giant-powder, etc. Since the first introduction of these explosives the care exercised in their manufacture has been greatly increased. It has been found to be of great importance that the nitro-glycerine should be pure and free from acid. To that end it is thoroughly washed with water, and also neutralized with an alkaline carbonate, so that now accidents resulting from spontaneous decomposition are almost unknown.

Gun-cotton.—Gun-cotton is formed by the action of concentrated nitric acid on cotton. The process of making gun-cotton consists essentially in exposing the dry cotton for a sufficiently long time to the action of a mixture of the strongest nitric acid with sulphuric acid, and in thoroughly washing the gun-cotton thus prepared to remove the excess of acid. In this reaction also the duty of the sulphuric acid is to take up the water, which is a secondary product.

By the method of Abel, a very perfect washing is obtained, and, in addition, the material is prepared in a form convenient to use and yet perfectly safe. The essential features of Abel's process are the reduction of the wet gun-cotton to a fine pulp, which can be easily washed, and the com-

pression of this pulp into convenient shapes. This product evidently cannot be used for certain purposes for which the fibre is required, such as in gunnery. This is not of importance, as gun-cotton is no longer so applied. For other military applications, such as demolitions, torpedoes, etc., the pulped and compressed gun-cotton is an admirable agent.

After the cotton has been converted into gun-cotton, and the latter is reduced to a pulp and thoroughly washed, the pulp is next to be separated from the large volume of water in which it is suspended, and compressed into cakes or disks. This is accomplished in two presses. The first press has 36 hollow cylinders, in which perforated plungers work upward. The plungers having been drawn down, the cylinders are filled with the mixture of pulp and water, and their tops covered with a weight. The plungers are then forced up by hydraulic power. The pulp is compressed, the water escaping through the perforations in the plungers. In the second press, the cylindrical masses of gun-cotton from the first press are more highly compressed, a pressure of 6 tons to the inch being applied. About 6 per cent. of water remains in the cakes, which can be removed by drying.

*Properties and Modes of Firing.*—The conversion of cotton into gun-cotton causes very little change in its appearance. The latter is somewhat harsher to the touch than the former. Gun-cotton is insoluble in and unaffected by water. If flame is applied to dry loose gun-cotton, it flashes up without explosion. Dry compressed gun-cotton burns rapidly but quietly when ignited by a flame. Moist compressed gun-cotton under the same circumstances burns away slowly. Even if a considerable quantity of gun-cotton is inflamed, it will burn away without explosion; but if the quantity is too great, the explosion of a part will be produced. In such cases the outer portion confines the inner sufficiently to cause its explosion. Dry, unconfined gun-cotton can be violently exploded by a small amount of fulminating mercury. Even in the compressed wet state, gun-cotton can be exploded; but to accomplish this it is necessary to apply the shock from the explosion of a small amount of the dry. For firing wet compressed gun-cotton, a "primer" is used, which is a cake of the dry, to which is attached a fulminate fuse. This primer must be inclosed in a water-proof bag or box. It is asserted that complete explosion of large charges of wet gun-cotton can be brought about in this way, but there is some doubt on this point. The firing-point of gun-cotton is about 360° F. (182° C.). It is not sensitive to friction or percussion. Imperfectly converted or badly washed, it is liable to spontaneous decomposition, which may result in explosion if the conditions are favorable. The pulped and compressed form is free from such danger, for since it can be fired wet there is no need of ever drying it, so it may be kept and used saturated with water.

Compressed gun-cotton is stored in the wet state. Care must be taken that it is not exposed to a temperature that will freeze the water in the cakes. If this occurs, they are liable to be disintegrated by the expansion of the water in freezing. In cold climates it is therefore advisable to store gun-cotton in pits below the reach of frost. For convenience in handling, gun-cotton is made into disks of various dimensions, or it may be pressed into slabs or blocks, which may be sawn, drilled, or cut as desired. The transportation of gun-cotton presents no special difficulties, since there is no danger of leakage, neither is it sensitive to blows.

The relative force of gun-cotton as compared with gunpowder is variously given from 4–6 to 1. The lower figure is probably nearly right, at any rate for wet gun-cotton.

*Nitrated gun-cotton* is made by soaking the compressed gun-cotton in a saturated solution of saltpetre (potassium nitrate) and drying. *Chlorated gun-cotton* is similarly made, using potassium chlorate instead of nitrate.

THE PICRATES.—The picrates are salts of picric acid. Picric acid is found in commerce, being used to dye silk and wool yellow. If the acid is heated, it takes fire and burns sharply and rapidly, without explosion. The picrates are all exploded with more or less violence by heat or blows. When used as explosive agents, they are mixed with potassium nitrate (saltpetre) or potassium chlorate. A large number of picrates are known, but the potassium and ammonium salts are the only ones that have been much used in explosive preparations.

*Potassium Picrate.*—Most violently explosive of the picrates. Potassium picrate and potassium chlorate form a mixture nearly as powerful as nitro-glycerine, but it is so sensitive to friction or percussion as to render it practically useless. With potassium nitrate instead of chlorate a less violent mixture is obtained, but one still too liable to accidental explosion.

*Ammonium Picrate.*—This salt has been proposed by Abel as an ingredient of a powder for bursting-charges of shells. The properties of ammonium picrate are very different from those of the potassium salt. If flame is applied to the former, it burns quietly, with a strong, smoky flame. If heated, it melts, sublimes, and burns without explosion. It is almost entirely unaffected by blows or friction. This salt, mixed with saltpetre, forms Abel's picric powder (Brugere's powder). It is more powerful than gunpowder and less violent than nitro-glycerine and gun-cotton. It is insensitive to ordinary means of ignition. If flame is applied to it, the particles touched burn, but the combustion does not readily extend to the others. Blows or friction do not explode it. It must be confined in order to develop its explosive force. It does not absorb moisture from the air, so that it may be stored and handled like gunpowder, and is at least equally safe and permanent.

THE FULMINATES.—The fulminates are salts of fulminic acid. The mercury salt is the only one of practical value. All of them are easily exploded, and some are excessively sensitive. Their explosions are very sharp from the extreme rapidity of their decomposition; but from the small amount of gas given off, the force exercised is not very great. The explosive effect obtained is of a local character.

*Fulminating Mercury* is formed by the action of mercuric nitrate and nitric acid upon alcohol. It explodes violently when forcibly struck, when heated to 186° C. (367° F.), and when touched with strong sulphuric acid or nitric acid, by sparks from flint and steel, or the electric spark. When wet it is inexplosive. It is therefore always kept wet, and dried in small amounts when wanted for use. Its explosive force is not much greater than that of gunpowder, but it is much more sudden in its action.

Detonators or detonating fuses are charged with pure fulminating mercury—15 to 25 grains in each. Fifteen grains is sufficient for nitro-glycerine or its preparations; 25 grains is used with compressed gun-cotton. In detonating fuses the fulminate should be contained in a copper cap or case, and must not be loose. Charging should be done with wet fulminate, as it is very dangerous to handle it when dry.

Explosive Mixtures.—These may be classed into two divisions: 1. Those containing nitrates; 2. Those containing chlorates.

1. *The Nitrate Class.*—Any of the nitrates may be used in explosive mixtures, but, practically, potassium nitrate (saltpetre) is the only one employed to any extent. With sulphur and charcoal, it makes up the numerous compositions, of which gunpowder is the most important.

Sawdust powder, or Schultze's white gunpowder, contains saltpetre. It is made by converting purified sawdust into a nitro-cellulose (resembling gun-cotton), and mixing this with the nitrate.

2. *The Chlorate Class.*—Chlorate mixtures are very sensitive to friction and percussion, and they explode with great sharpness. The following are examples: Potassium chlorate with rosin; potassium chlorate with galls (Horsley's powder); potassium chlorate with gambier (Oriental powder); potassium chlorate with sugar (used in "chemical" fuses); potassium chlorate with potassium ferrocyanide (white or German gunpowder); potassium chlorate with tannin (Erhardt's powder); potassium chlorate with sulphur (Pertuiset powder, used in explosive bullets).

Sprengel has published some interesting and important statements in regard to certain new classes of explosive mixtures. He finds that a variety of organic substances dissolved in nitric acid of 1.5 specific gravity explode by detonation. Nitro-benzol mixed with nitric acid in proper proportions gives a mixture which explodes with intense violence, if fired by a detonating fuse. Absorbed in silicious earth, it burns slowly when flame is applied, and is less sensitive to blows than dynamite or gun-cotton. Picric acid dissolves in nitric acid, forming a similar mixture. Many other combustibles may be thus used, but these mixtures are inconvenient to handle, since they contain concentrated nitric acid. Still their power and cheapness are so great that they may be of value.

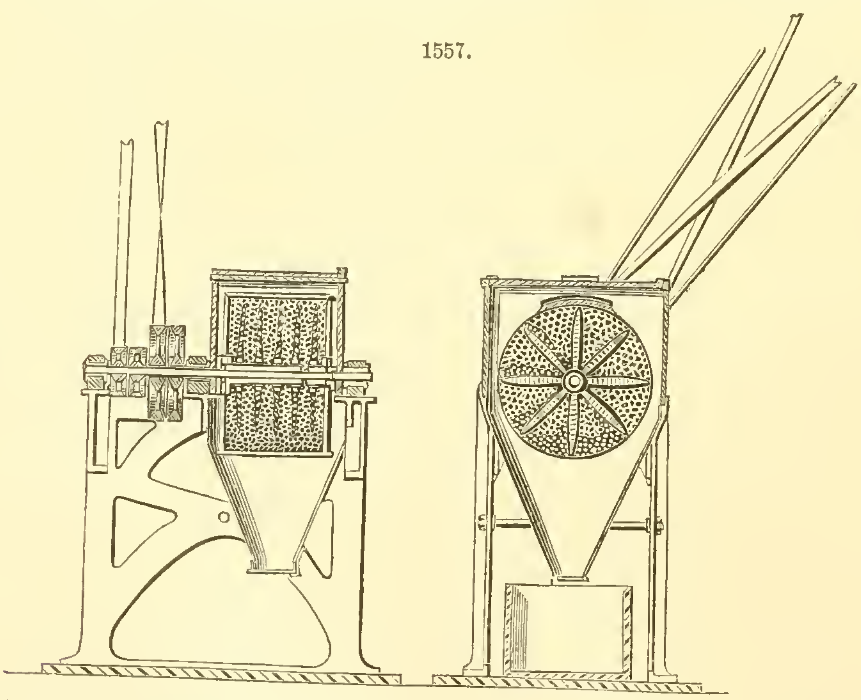
Gunpowder.*—The proportions of nitre, sulphur, and charcoal, most generally useful for ordinary purposes in gunpowder manufacture, all approximate to the percentages required by the formula $2KNO_3 + S + 3C$, supposing the charcoal to be pure carbon. The percentage composition is generally nitre 74.8, sulphur 11.9, and charcoal 13.3. The percentage of nitre varies from 70 to 80; that of sulphur and charcoal from 10 to 15 each. In the United States service, the regulation proportions are, nitre 75, charcoal 15, and sulphur 10.

The gas produced by the explosion of good gunpowder occupies nearly 900 times the volume of the powder itself; but owing to the high temperature, the space occupied by the gas at the moment of formation is probably 3,000 times greater than the volume of powder.

The woods used for charcoal are willow, alder, and black dogwood. The finest sulphur, containing in roughly distilled state 3 or 4 per cent. of impurities, is employed. It is thoroughly purified before use. The nitre is refined by boiling in water, filtering, crystallization, washing, and finally drying in hot chambers.

The ingredients, being finely ground, are weighed out in quantities of 50 lbs. each, and placed in a mixing machine, Fig. 1557, which consists of a hollow drum of gun-metal, rotated at 40 revolutions

1557.

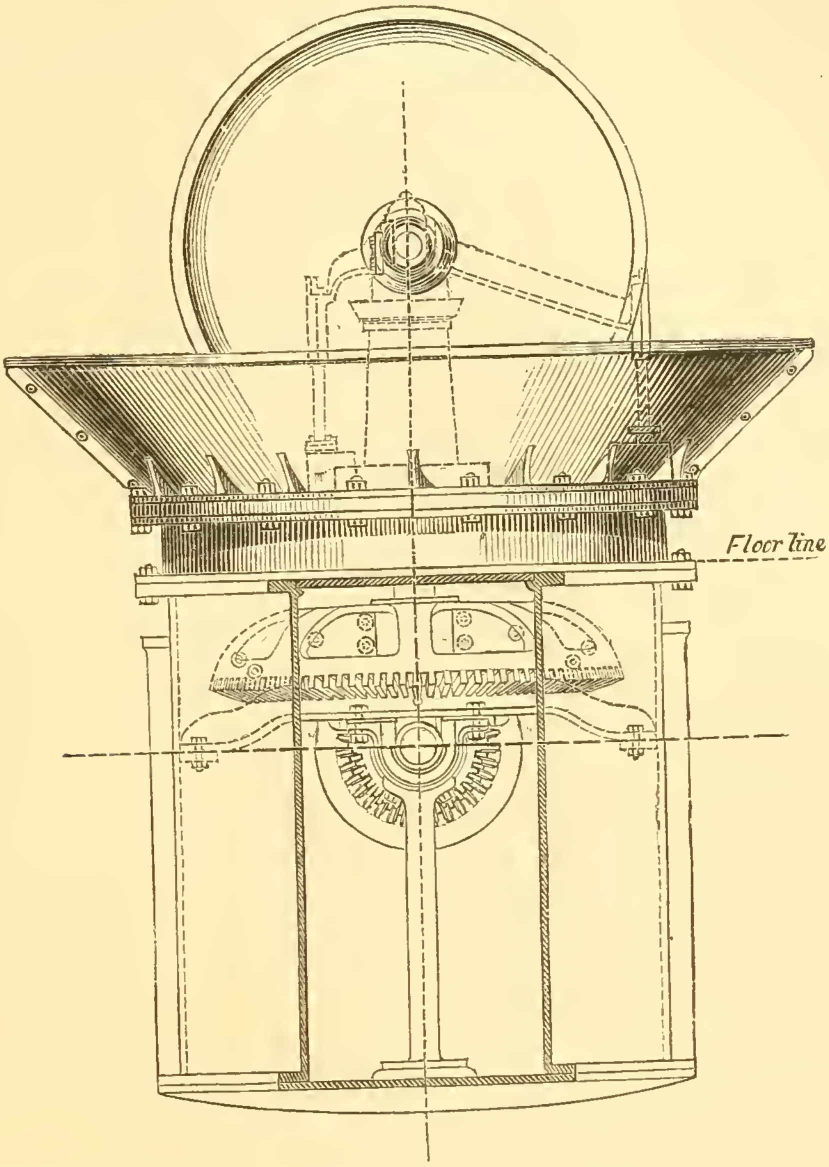


per minute. A shaft within this drum has arms or fliers, which revolve in opposite direction to that of the drum. About 5 minutes suffices for the mixing, and the ingredients are then passed through an 8-mesh wire sieve and sent to the incorporating mill. This machine, which is shown in Fig. 1558, is a pair of large edge-runners, of iron or stone, which revolve on a strong circular bed.

* Abridged from "Naval Ordnance and Gunnery," by Commander A. P. Cooke, U. S. N.

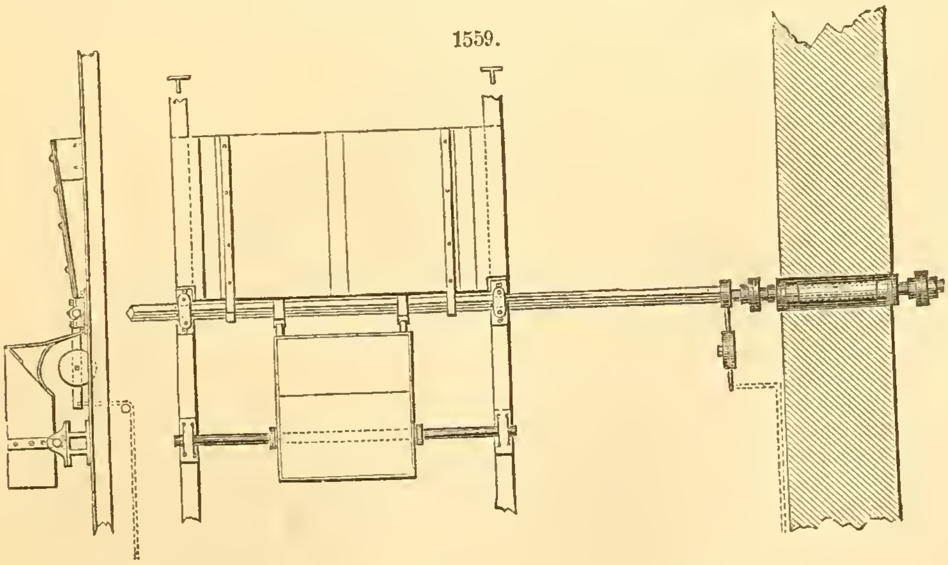
The runners weigh from 3 to 4 tons each, and are from 4 to 7 feet in diameter. One runner is placed on its spindle nearer the cross-head than the other, so that they describe different paths when

1558.




in motion. The cross-head is fixed on a vertical shaft actuated by machinery under the floor of the mill. It also carries a plough of wood shod with felt and leather, which travels around the bed in front of the runners and thus keeps the composition from working away from them. The speed is

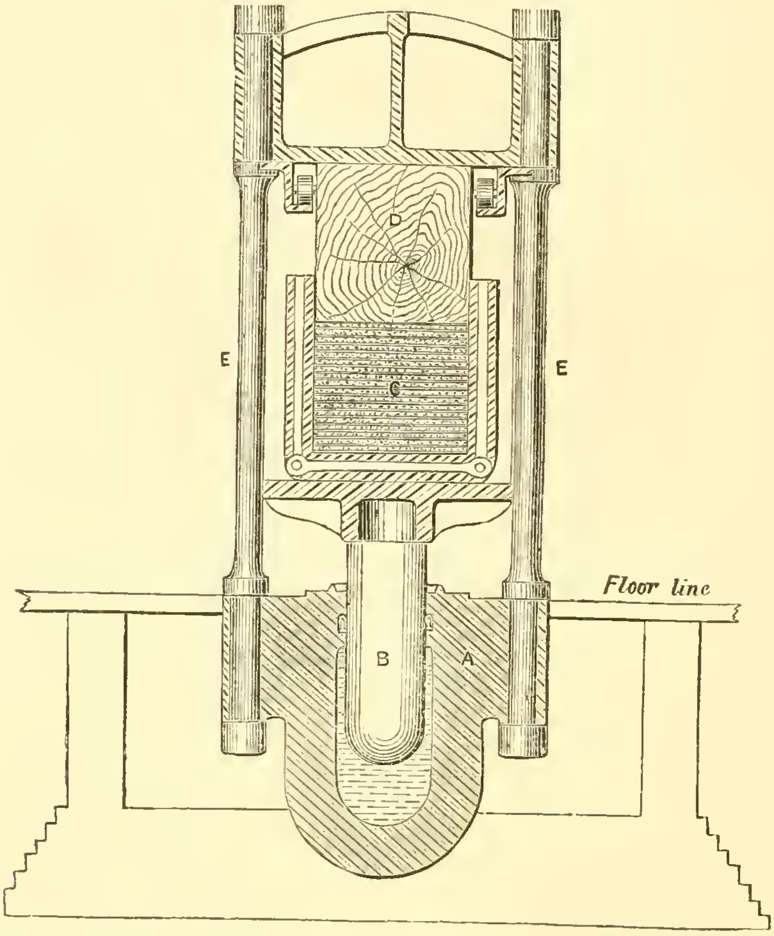
1559.



about 8 revolutions per minute, and about 2 pints of water is sprinkled over the charge. Fifty lbs. of cannon-powder requires $3\frac{1}{2}$ hours working under stone runners weighing $3\frac{1}{2}$ tons and making $7\frac{1}{2}$

revolutions per minute, but only 2½ hours under iron runners of 4 tons making 8 revolutions per minute. Small-arm (dogwood) powders require 5½ hours in the former mills, and 4 in the latter. Taking about 50 lbs. as the maximum amount which it is best to incorporate at one time under one pair of runners, it is easy to calculate the capacity of a gunpowder factory. A certain amount of work can be obtained from them, and no expedient can produce more. The manufacture cannot be hastened without incurring danger of explosion. A drenching apparatus, Fig. 1559, is usually erected over each pair of runners. It consists of a large shutter pivoted on a spindle which runs

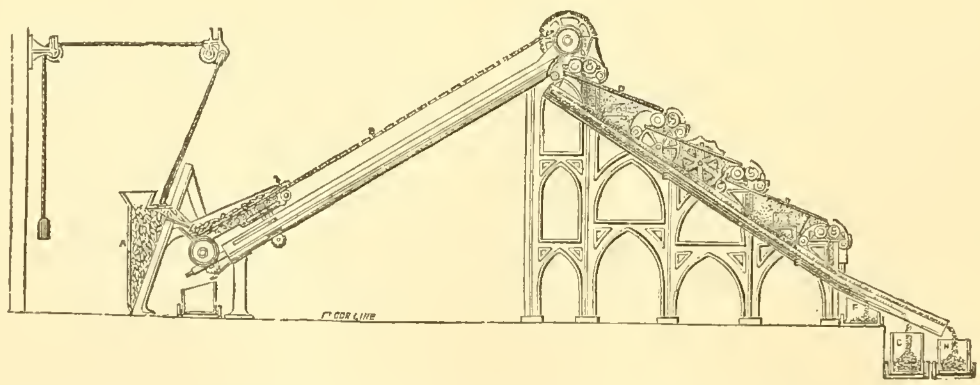
1560.




through the whole group of mills. Balanced on the pivot edge of the shutter is a large copper vessel filled with water, so arranged that at the slightest lift of the shutter it capsizes and drenches the charge beneath. An explosion of one mill, through all the shutters being on a single spindle, determines the wetting of the charges in all the others.

Gunpowder leaves the incorporating mill in a state of soft cake ("mill-cake"), partly dust. In order to convert it into hard cakes of the particular density found to give best results, it is pressed in layers between plates of copper in the hydraulic press. The construction of the press is exhibited

1561.

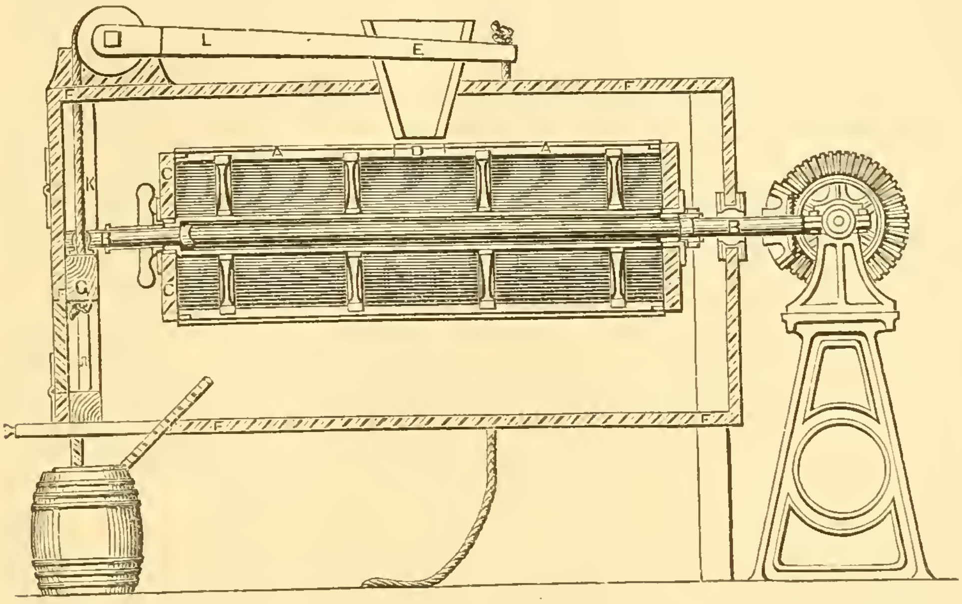


in Fig. 1560. *A* is the cylinder, *B* the ram, *C* the press-box, *D* the overhead block, and *E E* the standard. The granulation of the press-cake is effected by revolving toothed rollers of gun-metal, of which there are four, placed slanting, in each machine, Fig. 1561. They are placed in sliding bearings, so as to open and admit the passage of an excess of material without injury, and the two upper pairs have coarser teeth than the others. The press-cake is placed in a hopper at the back of the machine, and carried up on an endless band to the first pair of rollers, which rotate at 30 revolutions per minute. The grains thus produced fall through a short screen, and then through the

upper of a pair of long screens, and next through the lower one. The last permits the dust and minuter particles to fall through upon a sloping board, down which they slide to a vessel placed to receive them, but which retains the proper size of grain, which in turn rolls down into another receptacle at the bottom. The larger pieces, which escaped proper crushing by the first rollers, are shaken down by the first short screen into the second pair, to undergo the same process as at first, and so on with the third and fourth pairs of rollers. The granulating process appears to be the most dangerous of all.

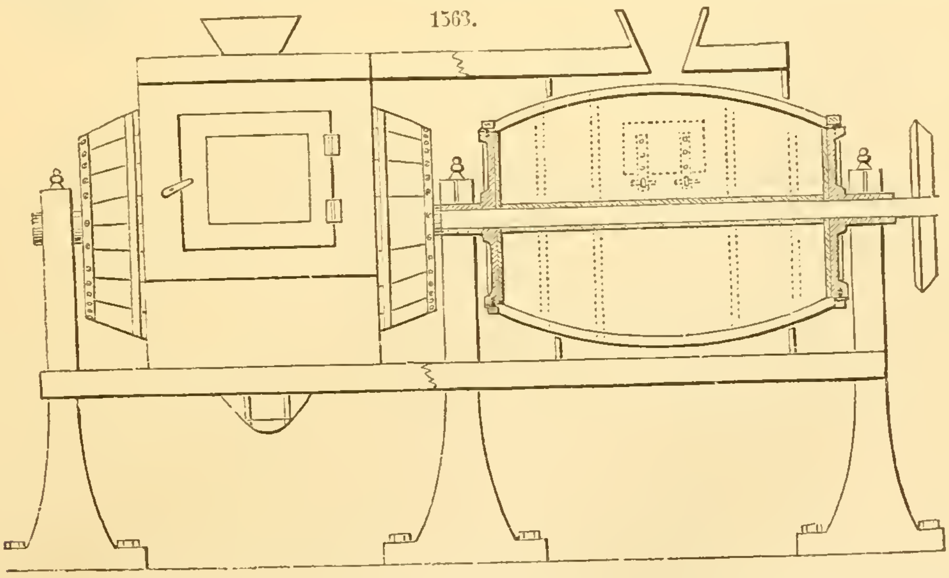
The powder is next freed from dust by placing it in revolving screens covered with cloth or wire mesh of various degrees of fineness, through which the dust escapes. The horizontal reel shown

1562.




in Fig. 1562 is usually employed for powder of large grain. It consists of a cylindrical skeleton of wooden hoops supported on a shaft by radial arms, the skeleton being covered with canvas or wire cloth *A*. The shaft *B* is of iron covered with wood. *C C* is the movable end, which can be drawn back. In the middle of the reel is a square opening *D* closed with a wooden door, through which the powder is run through a hopper *E* at the top of the parallel wood casing *F*, in which the reel is placed to confine the dust which escapes from it. *G* is a block carrying the bearing of the lower end, which can be raised or lowered by means of the rope *K* and lever *L* so as to put the reel on a slope. Slope-reels are not intended to retain the powder, but only to extract a certain portion of dust as it runs through them. They resemble the horizontal reels in general construction, except

1563.



that they have no ends and the shaft is set at a permanent slope. Each reel is provided with a feeding-hopper at its upper end, attached to which is a loose spout for guiding the powder into the reel.

Powder is glazed by causing the grains to rub against each other in rotating barrels; a little black lead is added in large-grained powders, to obtain a smoother surface. The barrels, Fig. 1563, are generally placed in line on one shaft, and are made of oak. They are usually about 5 feet long and 2½ feet in diameter. The shaft is cased in wood where it passes through them.

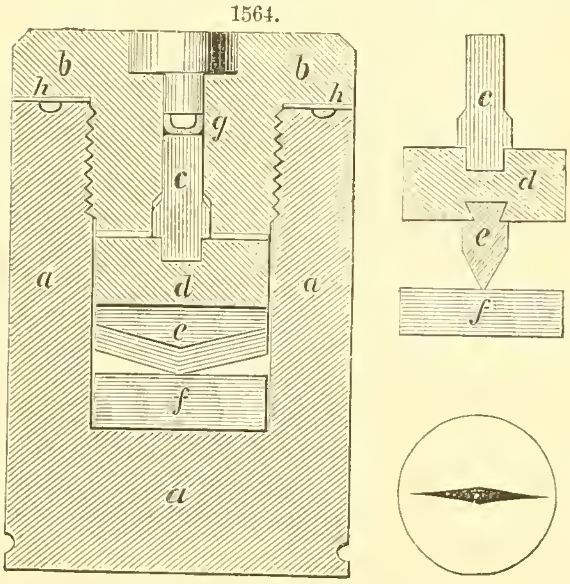
Drying is done in large chambers heated by steam from 125° to 130° F., and usually occupies one day. In fine-grained powders another dusting, called "finishing," is sometimes requisite.

The foregoing is a description of the English method of manufacturing gunpowder, from which

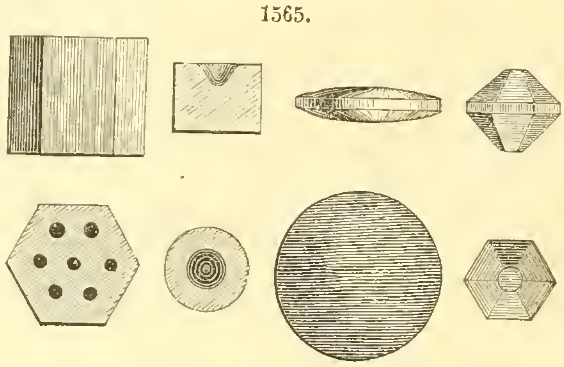
the American method differs in some particulars, arising principally from the fact that here the manufacturer deals with much larger quantities. The charges worked in the mixing and incorporating mills are from two to six times as large as above described, and the wheels in the incorporating mill, having to work such an increased quantity of material, weigh from 5 to 7½ tons each. It is stated that the capacity of this country for the production of powder exceeds that of the whole continent of Europe.

The disruptive force of gunpowder is measured by an instrument called a pressure-gauge. Three forms have been used, two of which were invented by General Rodman of the United States Ordnance Department. One is applied to the exterior of a gun, and communicates with the chamber by a narrow passage; the other is inserted in the cartridge-bag at the base of the charge, and remains in the gun after the discharge. The internal gauge, Fig. 1564, consists of a cylindrical box of steel, *a a*, with a cover *b b* screwed on. Through the axis of the cover is a cylindrical hole, in which a steel piston-rod *c* is fitted. Within the box is a thick disk of steel *d*, having a knife-edge *e* protruding from its lower face. This knife has a double shear, the edges of the two shears meeting at the centre in a very obtuse angle. At the bottom of the box the apex of the knife rests upon a disk of soft annealed copper *f*. The inner end of the steel rod is stepped into the steel knife-disk, and its outer end is a little below the top of the cover. A copper cup *g* rests upon the top of the rod, to serve as a gas-check. The pressure of the explosion is received by the rod, which communicates it to the knife, the apex of which sinks into the copper, giving a cut, the length of which serves as the measure of the pressure. *h h* is a copper washer. The smaller figures show the parts *c*, *d*, *e*, and *f*, enlarged and viewed from the side, and the indentation made on the copper disk. The working parts of the external gauge are quite similar to the foregoing, but the manner of housing them is different. Another form of gauge, invented by Captain Noble of the English Artillery, substitutes for the copper disk a short cylinder of copper, which is crushed by the pressure, the amount of crushing being employed to measure the pressure. This gauge is screwed into the wall of the gun in such a manner that the end of the rod receiving the pressure is very near the surface of the bore. Both

1564.




1565.



forms of gauge are liable to grave objections, since the measure obtained is essentially dynamical, while the quantity to be measured is statical. The English gauge is much inferior to the American, and cannot be relied upon to give even approximate indications of pressure from violent powder.

*Form of Powder.*—In the process of pressing the powder, by the methods used for many years, great irregularities of density always occur; and as the explosive property is more influenced by the density than by any other quality, the advantage of securing uniformity in this respect is manifest. Geometrical or "pellet" powder, Fig. 1565, requires a mould for each grain, whereby the density can be regulated with far more precision than by the old method. A leading variety of these geometrical forms is the prismatic, in which the grains are hexagonal prisms, about an inch in length and diameter. Each prism is perforated with 7 holes, one-tenth of an inch in diameter, parallel to the axis. They are symmetrically packed in a cartridge, of very small bulk in proportion to its weight. This form of powder is used for large rifled (Krupp) guns in the Russian, Prussian, and Austrian service, and its performance is excellent. Short cylinders have been used by the English, but they have been supplanted recently by pebble powder. Lenticular powder (grains in the form of lenses) has been tried in this country, but with indifferent results. The central portions, as a necessary result of the mode of pressing, were much less dense than the peripheral, and therefore burned too rapidly. Grains which had been ignited in the gun and extinguished in the air, and collected afterward, showed that the middle portions only had been consumed, leaving a ring of the denser portions. Ritter prismatic powder is simply the prismatic form just described, but without the perforations; it has been used in Belgium only. In recent experiments under the United States Government, pellets in the form of two truncated pyramids, having a common hexagonal base, have been employed; and the results appear to be better than those obtained by any other nation. The irregular, large-grained powder, used in heavy guns, receives the name "mammoth powder" in this country, and "pebble powder" in England; but these titles indicate no essential difference.

Gunpowder is classified, according to the size of the meshes through which the grain is sifted, into

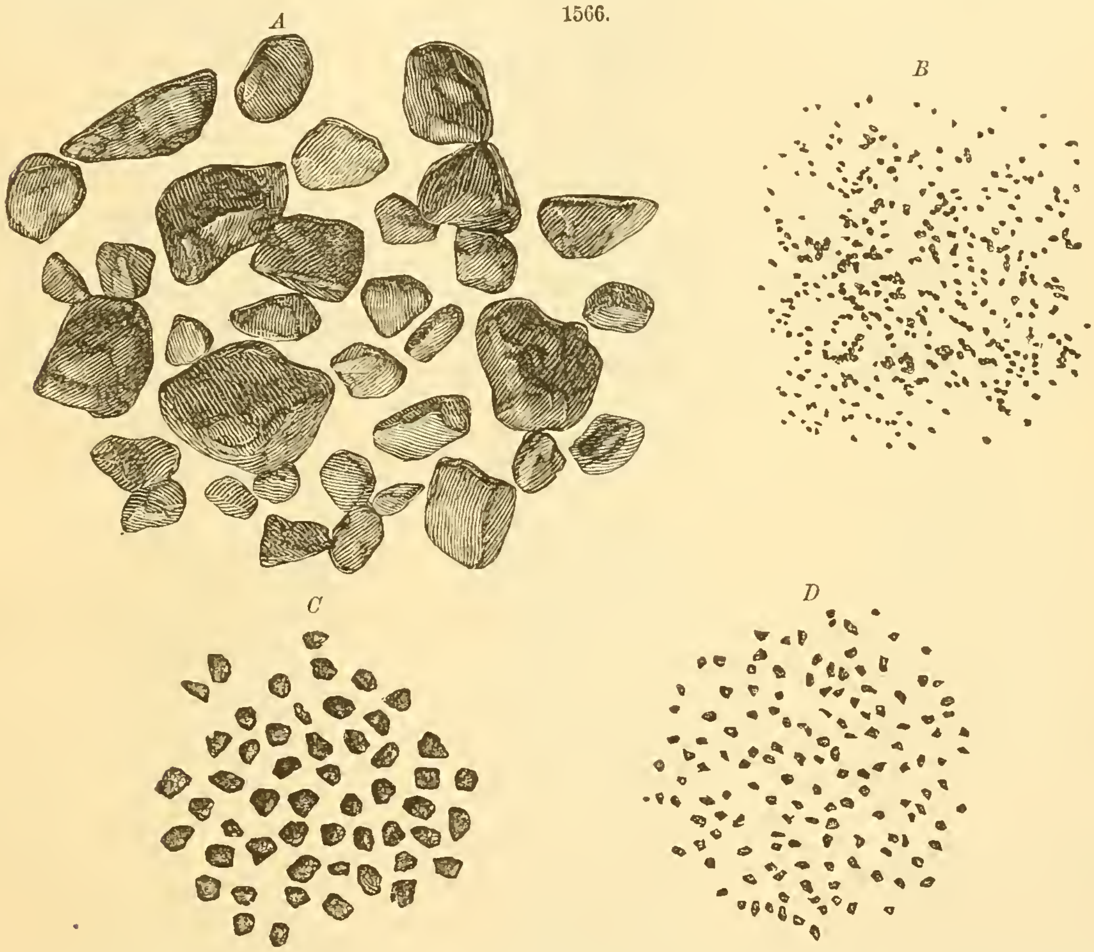
11 numbers, from 0 to 10, the latter being the finest rifle-powder, and the former the mammoth. In classifying it according to quality, each maker has his own method and nomenclature. In the United States Government service it is classified into: 1. Musket; 2. Mortar; 3. Cannon; 4. Mammoth powder. Two sieves are used for separating the grains of each class, all the grains being required to pass through the larger, and none through the smaller. The sizes of the meshes in decimal parts of an inch are:

| CLASS. | Large. | Small. |
|---|---|---|
| Musket | .06″ | .03″ |
| Mortar | .10 | .06 |
| Cannon | .35 | .25 |
| Mammoth | .90 | .60 |

The density of granular powder is either the absolute density, which is that of the grains themselves, or the gravimetric density, which is that of a quantity of grains with their interstices. The absolute density ranges from 1.60 to 1.80, the most common figure being about 1.75. The gravimetric density is generally about equal to that of water.

Sporting powder is made with especial care, of the purest saltpetre and sulphur, and the most care-

1566.




fully selected charcoal. The article is usually judged by the velocity it gives to a projectile, and the amount of fouling. In both respects erroneous judgments are likely to be formed, since the mode of charging is more frequently the cause of a poor performance than any defect in the quality of the powder. If a given brand is found to give a lower velocity than desired, it is better to increase the charge than to resort to a more violent kind; for the smaller charge is more apt to strain and erode the gun than the larger charge of milder powder. There is seldom any sufficient reason for excessive fouling, since this may generally be corrected by the use of a patch and lubricant.

While there has been but little if any change in the proportions of the ingredients, there has been a marked improvement in the quality of American gunpowder during the last few years, which improvement is mostly due to the greater care exercised in the selection and refining of materials, and in the manipulation during manufacture. Greater attention is now paid to the uniformity of the powder, particularly in the matter of density, which is found to exercise the greatest influence upon the action of the powder in the gun.

Fig. 1566 represents various sizes of powder made by the Laflin & Rand Powder Company. *A* shows the largest and *B* the smallest size of blasting powder; *C* and *D* show the largest and smallest sizes of rifle powder. The greater proportion of powder used for sporting purposes belongs to the rifle class. "Lightning" powder is the best quality, its largest size being the same as that of the largest rifle powder, and the smallest the same as the smallest blasting powder.

The foregoing figures fairly illustrate the ordinary sizes in use in this country, although different

manufacturers use different numerals to describe the same sizes. The above-named company report a gradual increase in the proportion of sales of the coarser-grained sporting powder from year to year during the last ten years. Sportsmen are gradually being educated to believe what has been so thoroughly demonstrated in connection with the use of powder in large guns for artillery and naval purposes, viz.: that less recoil and higher velocity are obtained by the use of an increased charge of larger-grained powder than was formerly thought suitable to use; and they are applying the same rule to the use of sporting powder with much satisfaction. The adoption of the breech-loading small arm admits of the use of the coarser-grained powder, which is not so easy to use when powder is required in the vent. In the present state of the art no general rule can be given to sportsmen whereby they can select a given sized grain of powder for a given diameter and length of gun; but it may be safely suggested to them that they will find advantage in using as coarse a powder as they can burn in their gun, and that if the size of the grain is increased the charge should also be gradually increased; the theory being that the coarse-grained powder burns slower than the fine one, other conditions being alike. The fine powder gives a "blow," and the coarse one a "push."

*Works for Reference.*—For a very complete description of modern explosive compounds, with references to all United States patents and the bibliography of the subject, see "Tunneling, Explosive Compounds, and Rock-Drills," Drinker, New York, 1878. "Ordnance and Naval Gunnery," Cooke, New York, 1875, contains bibliographical lists of military reports on experiments, etc., upon powder. See also *Engineering*, xxv., 38, for the beginning of a series of illustrated articles on gunpowder manufacture, and vol. xxv. of that journal for a review of explosives at the Paris Exposition of 1878. See also BLASTING, ELECTRO-BALLISTIC MACHINES, ORDNANCE, PROJECTILES, AND TORPEDOES.

FANNING-MILL. See AGRICULTURAL MACHINERY.

FANS. See BLOWERS.

FEED-CUTTER. See AGRICULTURAL MACHINERY.

FILES. Files and rasps have three distinguishing features: 1. Their length, which is always measured exclusively of their tangs; 2. Their cut, which relates not only to the character, but also to the relative degrees of coarseness of the teeth; 3. Their kind or name, which has reference to the shape or style. In general the length of files bears no fixed proportion to either their width or thickness, even though they be of the same kind. The *tang* is the spike-shaped portion of the file prepared for the reception of a handle, and in size and shape should always be proportioned to the size of the file and to the work to be performed. The *heel* is that part of the file to which the tang is affixed.

CUT.—Of the cut of files we may say that it consists of three distinct forms, viz.: *single-cut*, *double-cut*, and *rasp*; each of which has different degrees of coarseness, designated by terms, as follows, viz.:

| SINGLE-CUT. | DOUBLE-CUT. | RASP. |
|---|---|---|
| Rough, | Coarse, | Coarse, |
| Coarse, | Bastard, | Bastard, |
| Bastard, | Second-cut, | Second-cut, |
| Second-cut, | Smooth, | Smooth. |
| Smooth. | Dead-smooth. | |

The terms *rough*, *coarse*, *bastard*, *second-cut*, *smooth*, and *dead smooth* have reference only to the coarseness of the teeth; while the terms *single-cut*, *double-cut*, and *rasp* have special reference to the *character* of the teeth.

*Single-Cut.*—The single-cut files (the coarser grades of which are sometimes called *floats*) are those in which the teeth are unbroken, the blanks having had a single course of chisel-cuts across their surface, arranged parallel to each other, but with a horizontal obliquity to the central line, varying from 5° to 20° in different files, according to requirements. Its several gradations of coarseness are designated by the terms *rough*, *coarse*, *bastard*, *second-cut*, and *smooth*. (See Fig. 1567.) The *rough* and *coarse* are adapted to files used upon soft metals, as lead, pewter, etc., and to some extent upon wood. The *bastard* and *second-cut* are applied principally upon files used to sharpen the thin edges of saw-teeth, which from their nature are very destructive to the delicate points of the double-cut. The *smooth* is seldom applied upon other than the round files, and the backs of the half-rounds.

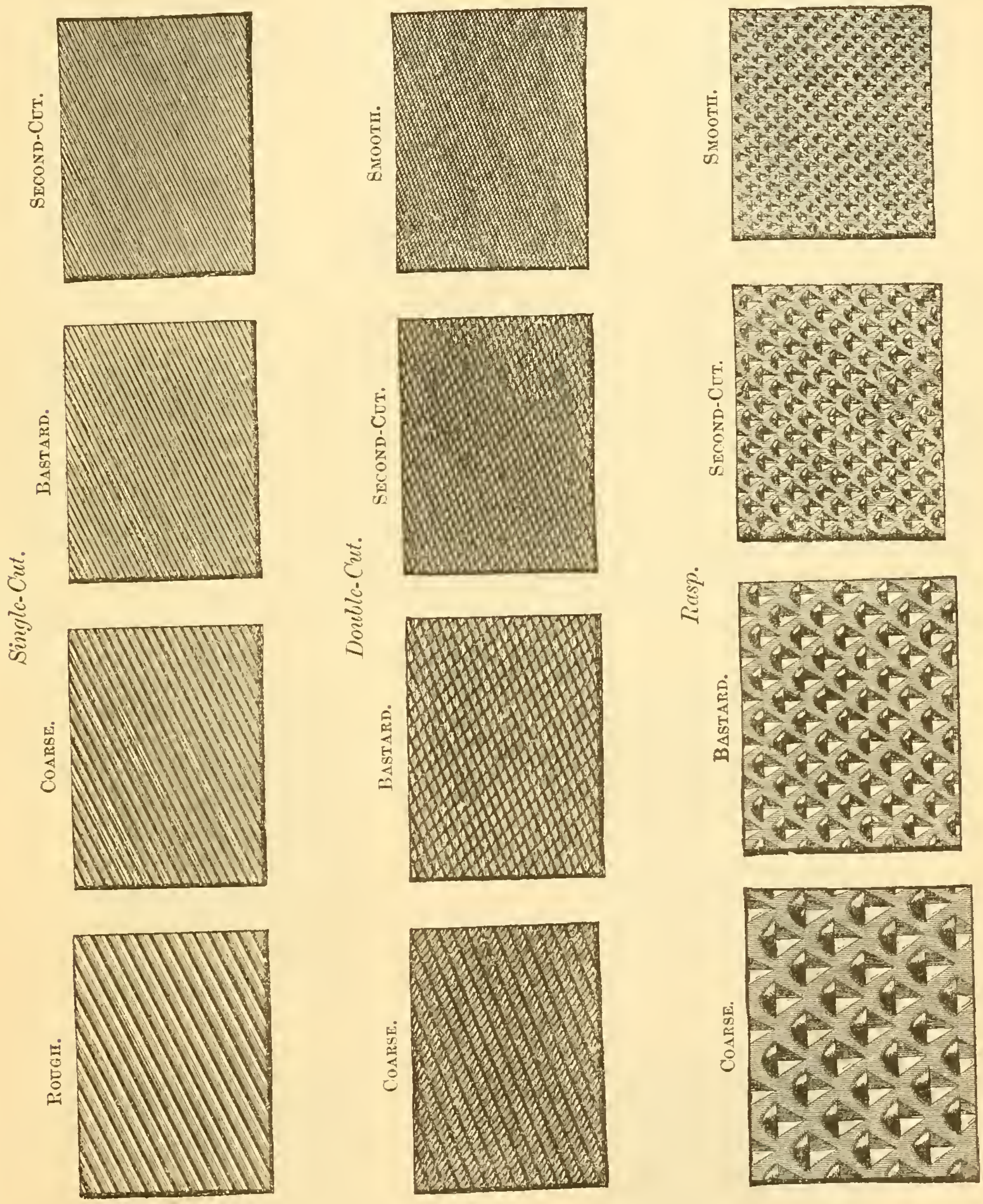
*Double-Cut.*—Files having two courses of chisel-cuts crossing each other are called *double-cut*. The first course is called the *over-cut*, and has a horizontal obliquity with the central line of the file, ranging from 35° to 55°. The second course, which crosses the first, and in most double-cuts is finer, is called the *up-cut*, and has a horizontal obliquity varying from 5° to 15°. These two courses fill the surface of the file with teeth, inclining toward its point, the points of which resemble somewhat, when magnified, those of the diamond-shaped cutting tools in general use. This form of cut is made in several gradations of coarseness, which are designated by the terms *coarse*, *bastard*, *second-cut*, *smooth*, and *dead-smooth*, the first four of which are very clearly illustrated in Fig. 1567. The *dead-smooth* is exactly like the *smooth*, but considerably finer, and little called for. The *double-cut* is applied to most of the files used by the machinist, and in fact to much the larger number in general use.

*Rasp-cut.*—Rasps differ from the single- or double-cut files in the respect that the teeth are disconnected from each other, each tooth being made by a single pointed tool, denominated by file-makers a *punch*; the essential requirement being that the teeth thus formed shall be so irregularly intermingled as to produce, when put to use, the smoothest possible work consistent with the number of teeth contained in the surface of the rasp. Rasps, like files, have different degrees of coarseness, designated as *coarse*, *bastard*, *second-cut*, and *smooth*. The character and general coarseness of these cuts, as found in the different sizes, are also shown in Fig. 1567. Generally speaking, the *coarse* teeth are applied to rasps used by horse-shoers; the *bastard*, to those used by carriage-makers and wheelwrights; the *second-cut*, to shoe rasps; and the *smooth*, to the rasps used by cabinet-makers.

*Floats.*—Fig. 1572 represents a *float* used for filing lead. It will be seen that the teeth are

nearly straight across the file, and are very open, both of these features being essential requirements. While employed to some extent upon bone, horn, and ivory, these files are principally used by plumbers and workers in lead, pewter, and similar soft metals.

Several kinds of floats are made with coarse, shallow, and sharp teeth; these teeth could not be cut with the chisel and hammer in the ordinary manner, but are made with a triangular file. In Fig. 1568, *a* to *l* represent the sections of several of these floats, which have teeth at the parts indicated by the double lines; for instance, *a* is the float, *b* the *graille*, *c* the *found*, *d* the *carlet*, *e* the *topper*, used by the horn and tortoise-sheel comb-makers. The floats *f* to *i* are used by ivory-carvers for the handles of knives, and in the preparation of works the carving of which is to be completed by scoopers and gravers. *k* and *l* are used in inlaying tools in their handles; *k* is made of various widths, and is generally thin, long, and taper; *l* is more like a keyhole saw. The larger of the



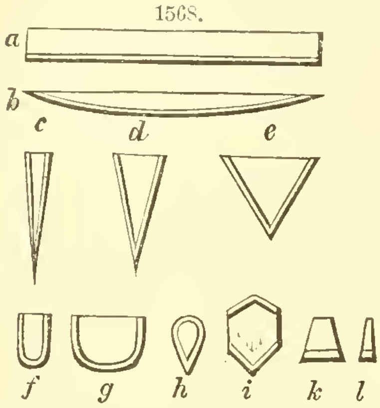
1567.

floats, such as those *a* to *c*, used by the comb-makers, are kept in order principally by the aid of a burnisher, represented in two views in Fig. 1569; the blade is about 2 inches long, 1 inch wide, and 1-16th thick; the end is mostly used, and is forcibly rubbed, first on the front edge of every tooth, as at *a*, Fig. 1570, and then on the back, as at *b*, by which means a slight burr is thrown up on every tooth, somewhat like that on the joiner's scraper; but in this art the burnisher is commonly named a *turn-file*.

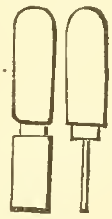
The *quannet* is a float resembling Fig. 1597, but having coarse-filed teeth, of the kind just described; it may be considered as the ordinary flat file of the horn and tortoise-shell comb-makers; and in using the quannet, the work is mostly laid upon the knee as a support. An ingenious artisan in this branch, Mr. Michael Kelly, invented the quannet represented in Figs. 1570 and 1571. The stock consists of a piece of beech-wood, in which, at intervals of about one-quarter of an inch, cuts

inclined nearly 30° with the face are made with a thin saw; every cut is filed with a piece of saw-plate. The edges of the plates and wood are originally filed into the regular float-like form, and the burnisher is subsequently resorted to as usual. The main advantage results from the small quantity of steel it is necessary to operate upon when the instrument requires to be restored with the file. From this circumstance, and also from its less weight, the wooden quannet, Fig. 1570, is

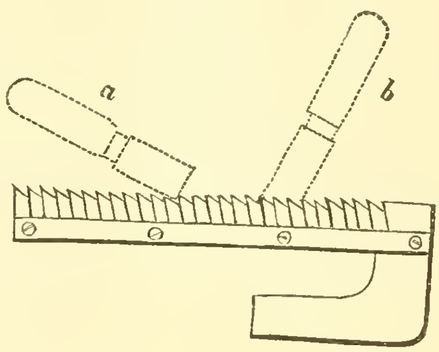
1568.



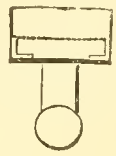

1569.



1570.




1571.

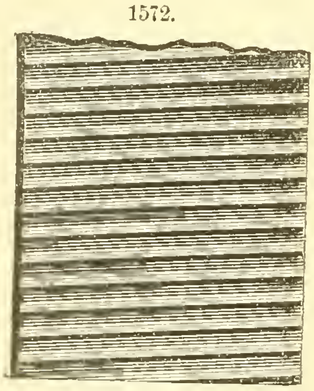


made of nearly twice the width of the steel instrument, Fig. 1597, and the face is slightly rounded, the teeth being sometimes inserted square across, as in a float, at other times inclined some 30°, as in a single-cut file.

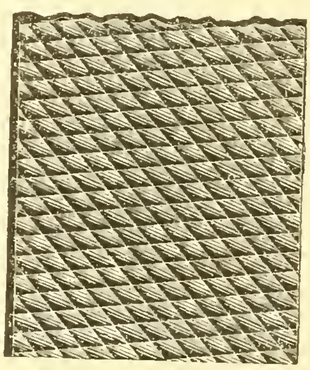
*Brass Files.*—Figs. 1573, 1574, and 1575 are respectively coarse, bastard, and finishing second-cut files for brass. Fig. 1573, being open in both its over- and up-cut, is not expected to file fine, but fast, and is adapted for very rough work on the softer metals, as in filing off sprues from brass and bronze castings, filing the ends of rods, and work of a similar nature. It is also to some extent used upon wood. The essential difference between the bastard file shown in Fig. 1574 and that just described is the degree of fineness of the up-cut, which is nearly straight across the tool. This form of teeth, which may be applied to any of the finer cuts, and upon any of the shapes usually made *double-cut*, is especially adapted to finishing brass, bronze, copper, and similar soft metals, and is not so well adapted to the rougher work upon these metals as the *coarse brass file* previously described.

Fig. 1575 is a finishing file. The first or *over-cut*, in this case, is very fine, and, contrary to the general rule, has the least obliquity; while the *up-cut* has an unusual obliquity, and is the coarser of the two cuts. The advantages in this arrangement of the teeth are that the file will finish finer, and, by freeing itself from the filings, is less liable to clog or pin, than files cut for general use. This

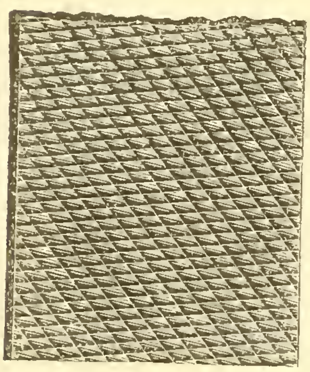
1572.



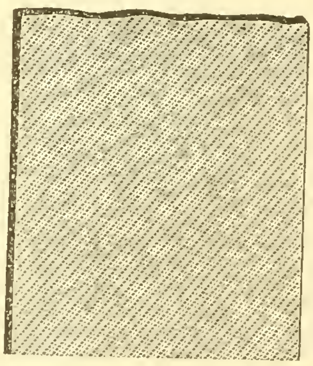
1573.



1574.



1575.



form of cut is especially useful when a considerable quantity of finishing of a light nature is required upon steel or iron. It is not recommended for brass or the softer metals, nor should it be made of a coarser grade than second-cut.

Kinds of Files.—The names of files are often derived from their purposes, as in saw-files, slitting, warding, and cotter files; the names of others from their sections, as square, round, and half-round

files. Files of all the sections represented in the groups, Figs. 1576 to 1578, are more or less employed, although many of them are almost restricted to particular purposes.

*Taper files*, or *taper flat files*, are made of various lengths from about 4 to 24 inches, and are rectangular in section, as in *B*, Fig. 1576; they are considerably rounded on their edges, and a little also in their thickness, their greatest section being toward the middle of their length or a little nearer to the handle, whence these files are technically called "bellied;" they are cut both on their faces and edges with teeth of four varieties, namely, rough, bastard, second-cut, and smooth-cut teeth. Taper flat files are in extremely general use among smiths and mechanics, for a great variety of ordinary works.

*Hand files* or *flat files* resemble the above in length, section, and teeth, but the hand files are nearly parallel in width, and somewhat less taper in thickness than the foregoing. Engineers, machinists, mathematical-instrument makers, and others give the preference to the hand file for flat surfaces and most other works.

*Cotter files* are always narrower than hand files of the same length and thickness; they are nearly flat on the sides and edges, so as to present almost the same section at every part of their length, in which respect they vary from 6 to 22 inches. Cotter files are mostly used in filing grooves for the cotters, keys, or wedges used in fixing wheels on their shafts, whence their name.

*Pillar files* also somewhat resemble the hand files, but they are much narrower, somewhat thinner, as in *C*, and are used for more slender purposes, or for completing works that have been commenced with the hand files. Pillar files have commonly one safe edge, and vary from 3 to 10 inches in length.

*Half-round files* are nearly of the section *L*, notwithstanding that the name implies the semicircular section; in general the curvature only equals the fourth to the twelfth part of the circle.

*Triangular files* are of the section *R*, and from 2 to 16 inches long; they are used for internal angles more acute than the rectangle, and also for clearing out square corners.

*Cross files*, or crossing files, are of the section *M*, or circular on both faces, but of two different curvatures.

*Round files*, of the section *I*, range from the length of 2 to 18 inches; they are in general taper, and much used for enlarging round holes.

*Square files* measure in general from 2 to 18 inches in length, and are mostly taper.

*Equaling files* are files of the section *D*. In width they are more frequently parallel than taper; in thickness they are always parallel. They are in general cut on all faces, and range from 2 to 10 inches long.

*Knife files* are of the section *T*, and in general very acute on the edge; they are made from 2 to 7 inches long, and are as frequently parallel as taper.

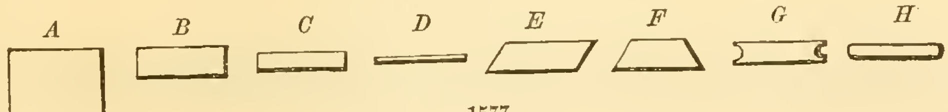
*Slitting files*, called also *feather-edged files*, resemble the last in construction and purpose, except in having, as in section *V*, two thin edges instead of one; they are almost always parallel.

*Rubbers* are strong heavy files, generally made of an inferior kind of steel; they measure from 12 to 18 inches long, from ¾ to 2 inches on every side, and are made very convex; they are frequently designated by their weight alone, which varies from about 4 to 15 lbs. Rubbers are nearly restricted to the square and triangular sections *A* and *R*. Some few rubbers are made nearly square in section, but with one side rounded, as if the sections *K* and *B* were united; these are called *half-thick*.

Many artisans, and more particularly the watchmakers, require other files than those described, and it is therefore proposed to add the names of some of the files to which the sections refer, premising that such names as are printed in *Italics* designate small files especially used in watchmaking.

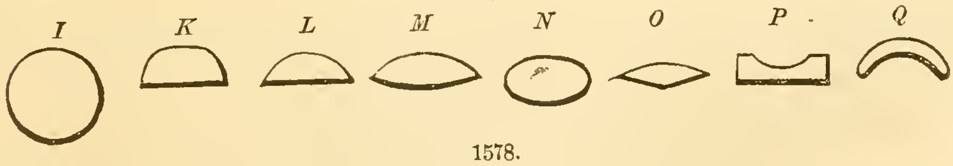
1576.

*Sections derived from the Square.*



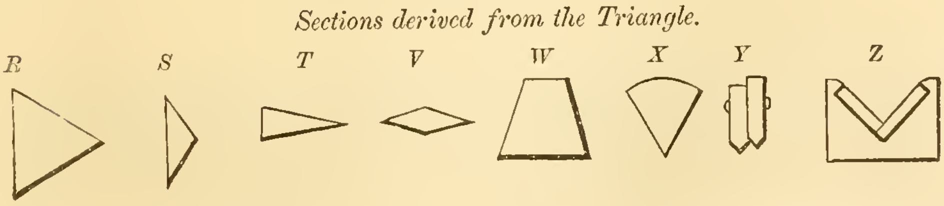

1577.

*Sections derived from the Circle.*




1578.

*Sections derived from the Triangle.*




*Names of some of the Files corresponding with the Sections A to Z, in Figs.* 1576 *to* 1578.

*A.* Square files, both parallel and taper, some with one safe side; also square rubbers.
*B.* When large, cotter files; when small, *verge* and *pivot* files.
*C.* Hand files, parallel and flat files; when small, *pottance* files; when narrow, pillar files; to these nearly parallel files are to be added the taper flat files.

*D.* When parallel, equaling, *clock-pinion*, and *endless-screw* files; when taper, slitting, entering, warding, and *barrel-hole* files.

*E.* *French pivot* and *shouldering files*, which are small, stout, and have safe edges; when made of large size, and right and left, they are sometimes called parallel V files, from their suitability to the hollow V's of machinery.

*F.* Name and purpose similar to the last.

*G.* Flat file with hollow edges, principally used as a nail file for the dressing-case.

*H.* Pointing mill-saw file, round-edge equaling file, and round-edge joint file; all are made both parallel and taper.

*I.* Round file, gulleting saw-file, made both parallel and taper.

*K.* Frame saw-file, for gullet teeth.

*L.* Half-round file. *Nicking* and *piercing* files, also cabinet floats and rasps; all these are usually taper. Files of this section which are small, parallel, and have the convex side uncut, and have also a pivot at the end opposite the tang, are called *round-off files.*

*M.* Cross or crossing files, also called double half-rounds.

*N.* Oval files; oval gulleting files for large saws, called by the French *limes à double dos; oval-dial file* when small.

*O.* *Balance-wheel* or *swing-wheel files*, the convex side cut, the angular sides safe.

*P.* Swaged files, for finishing brass mouldings; sometimes the hollow and fillets are all cut.

*Q.* The curvilinear file.

*R.* Triangular, three-square, and saw-files, also triangular rubbers, which are cut on all sides.

*S.* Cant file, probably named from its suitability to filing the insides of spanners, for hexagonal and octagonal nuts, or, as these are generally called, six- or eight-*canted* bolts and nuts; the cant files are cut on all sides.

*T.* When parallel, *flat-dovetail*, *banking*, and *watch-pinion* files; when taper, knife-edge files. With the wide edge round and safe, files of the section *T* are known as moulding files and *clock-pinion* files.

*V.* Screw-head files, feather-edged files, *clock-* and *watch-slitting* files.

*W.* Is sometimes used by engineers in finishing small grooves and keyways, and is called a valve file, from one of its applications.

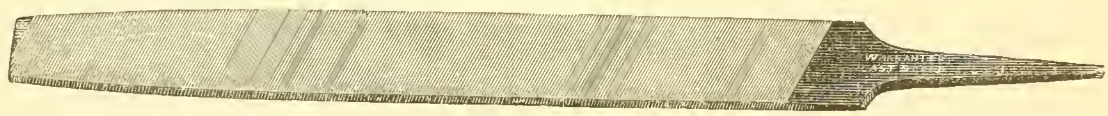
*X.* A file compounded of the triangular and half-round file, and stronger than the latter; similar files with three rounded faces have also been made for engineers.

*Y.* Double or checkering files, used by cutlers, gunmakers, and others. The files are made separately and riveted together, with the edge of the one before that of the other, in order to give the equality of distance and parallelism of checkered works, just as in the double saws for cutting the teeth of racks and combs.

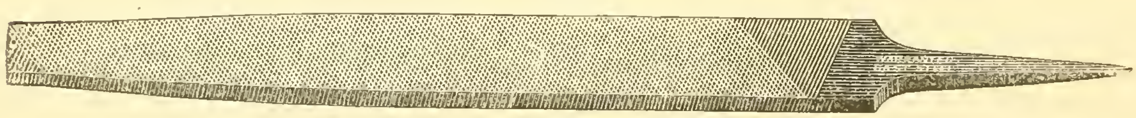
*Z.* Double file, made of two flat files fixed together in a wood or metal stock; this was invented for filing lead pencils to a fine conical point.

In Figs. 1579 to 1583 are represented full views of different shapes of files manufactured by the

1579.

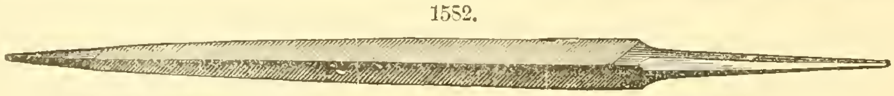


1580.

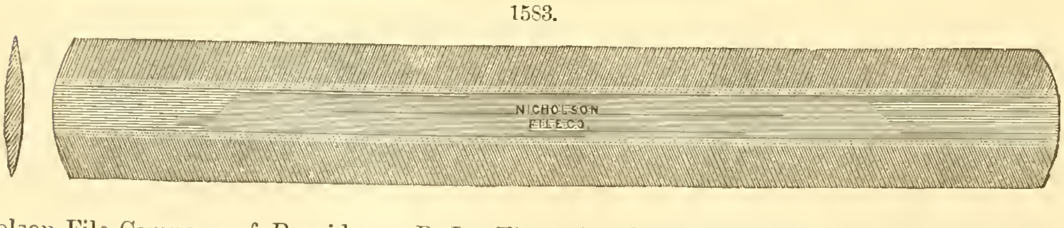


1581.

1582.



1583.



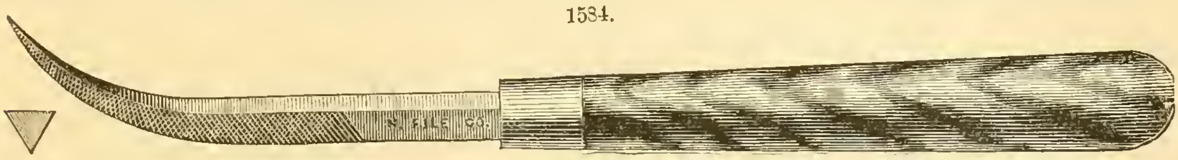

Nicholson File Company of Providence, R. I. Fig. 1579 shows the general form of a quadrangular file; Fig. 1580 is a flat file; Fig. 1581, a round file; Fig. 1582, a triangular file; and Fig. 1583, a roller file. The roller file is designed for use in a machine for filing the flutes of feed-rollers in cotton-spinning machinery. It is usually 4 inches in length and second-cut, single.

Fig. 1584 represents a bent riffler. This tool is made in a variety of forms and of different cuts.

It is used principally by carvers in wood, metals, marble, and stone; also in shaping and finishing in and about the many irregular pieces of pattern work.

The Manufacture of Files.—The pieces of steel, or the blanks, intended for files are forged out of bars of steel that have been either tilted or rolled as nearly as possible to the sections required, so as to leave but little to be done at the forge; the blanks are afterward annealed with great caution, so that in neither of the processes the temperature known as the blood-red heat may be exceeded. The surfaces of the blanks are now rendered accurate in form and quite clean in surface either by filing or grinding. For the smaller files, the blanks are mostly filed into shape as the more exact method; for the larger, the blanks are more commonly ground on large grindstones as the more expe-

1584.



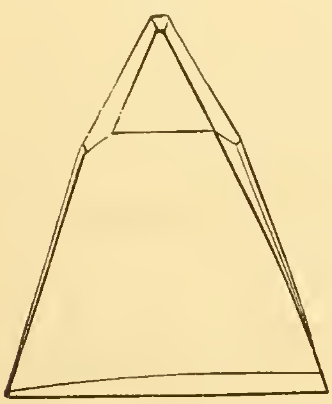
ditious method; in some few cases the blanks are planed in the planing machine, for those called *dead-parallel files*. The blank before being cut is slightly greased, that the chisel may slip freely over it.

The file-cutter is seated before a square stake or anvil, and places the blank straight before him, with the tang toward his person; the ends of the blank are fixed down by two leather straps or loops, one of which is held fast by each foot.

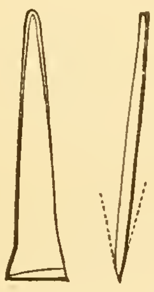
The largest and smallest chisels commonly used in cutting files are represented in two views, and half size, in Figs. 1585 and 1586. The first is a chisel for large rough files; the length is about 3 inches, the width 2¼ inches, and the angle of the edge about 50°; the edge is perfectly straight, but the one bevel is a little more inclined than the other, and the keenness of the edge is rounded off, the object being to indent rather than cut the steel; this chisel requires a hammer of about 7 or 8 lbs. weight. Fig. 1586 is the chisel used for small superfine files; its length is 2 inches, the width half an inch; it is very thin, and sharpened at about the angle of 35°; the edge is also rounded, but in a smaller degree: it is used with a hammer weighing only one or two ounces, as it will be seen the weight of the blow mainly determines the distance between the teeth. Other chisels are made of intermediate proportions, but the width of the edge always exceeds that of the file to be cut.

The first cut is made at the point of the file; the chisel is held in the left hand, at a horizontal angle of about 55° with the central line of the file, as at *a a*, Fig. 1587, and with a vertical inclina-

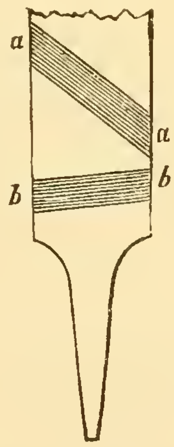
1585.



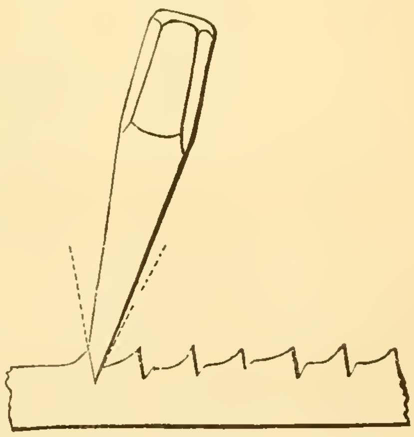
1586.



1587.




1588.



tion of about 12° to 4° from the perpendicular, as represented in Figs. 1585 and 1586, supposing the tang of the file to be on the left-hand side. The following are nearly the usual angles for the vertical inclination of the chisels, namely: for rough rasps, 15° beyond the perpendicular; rough files, 12°; bastard files, 10°; second-cut files, 7°; smooth-cut files, 5°; and dead-smooth-cut files, 4°. The blow of the hammer upon the chisel causes the latter to indent and slightly to drive forward the steel, thereby throwing up a trifling ridge or *burr;* the chisel is immediately replaced on the blank, and slid from the operator until it encounters the ridge previously thrown up, which arrests the chisel or prevents it from slipping further back, and thereby determines the succeeding position of the chisel. The chisel, having been placed in its second position, is again struck with the hammer, which is made to give the blows as nearly as possible of uniform strength; and the process is repeated with considerable rapidity and regularity, 60 to 80 cuts being made in one minute, until the entire length of the file has been cut with inclined, parallel, and equidistant ridges, which are collectively denominated the *first course.* So far as this one face is concerned, the file, if intended to be single-cut, would be then ready for hardening; and when greatly enlarged, its section would be somewhat as in Fig. 1588. The teeth of some single-cut files are much less inclined than 55°; those of floats are in general square across the instrument.

Most files, however, are double-cut, or have two series or *courses* of chisel cuts: and for these the surface of the file is now smoothed by passing a smooth file once or twice along the face of the teeth, to remove only so much of the roughness as would obstruct the chisel from sliding along the face in receiving its successive positions, and the file is again greased. The second course of teeth is now

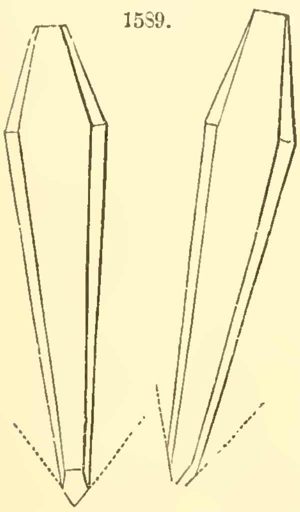
cut, the chisel being inclined vertically as before, or at about 12°, but horizontally about 5° to 10° from the rectangle, as at *b b*, Fig. 1587; the blows are now given a little less strongly, so as barely to penetrate to the bottom of the first cuts, and consequently the second course of cuts is somewhat finer than the first. The two series of courses fill the surface of the file with teeth which are inclined toward the point of the file, and that when highly magnified much resemble in character the points of cutting tools generally, as seen in Fig. 1588. If the file is flat and to be cut on two faces, it is now turned over; but to protect the teeth from the hard face of the anvil, a thin plate of pewter is interposed. Triangular and other files require blocks of lead having grooves of the appropriate sections to support the blanks, so that the surface to be cut may be placed horizontally. Taper files require the teeth to be somewhat finer toward the point, to avoid the risk of the blank being weakened or broken in the act of its being cut, which might occur if as much force were used in cutting the teeth at the point of the file as in those at its central and stronger part.

Eight courses of cuts are required to complete a double-cut rectangular file that is cut on all faces, but eight, ten, or even more courses are required in cutting only the *one* rounded face of a half-round file. There are various objections to employing chisels with concave edges, and therefore in cutting round and half-round files the ordinary straight chisel is used and applied as a tangent to the curve. It will be found that in a smooth half-round file one inch in width, about 20 courses are required for the convex side, and two courses alone serve for the flat side. In some of the double-cut gullet-tooth saw-files, of the section *K*, as many as 23 courses are sometimes used for the convex face, and but two for the flat. The same difficulty occurs in a round file, and the surfaces of curvilinear files do not therefore present, under ordinary circumstances, the same uniformity as those of flat files.

Hollowed files are rarely used in the arts, and when required it usually becomes imperative to employ a round-edged chisel, and to cut the file with a single course of teeth.

The teeth of rasps are cut with a punch, which is represented in two views, Fig. 1589. The punch for a fine cabinet rasp is about 3½ inches long, and five-eighths of an inch square at its widest part. Viewed in front, the two sides of the point meet at an angle of about 60°; viewed edgewise, or in profile, the edge forms an angle of about 50°, the one face being only a little inclined to the body of the tool. In cutting rasps, the punch is sloped rather more from the operator than the chisel in cutting files, but the distance between the teeth of the rasp cannot be determined, as in the file, by placing the punch in contact with the burr of the tooth previously made. By dint of habit, the workman moves or, technically, *hops* the punch the required distance; to facilitate this movement, he places a piece of woolen cloth under his left hand, which prevents his hand from coming immediately in contact with and adhering to the anvil. The teeth of rasps are cut in rather an arbitrary manner, and to suit the whims rather than the necessities of the workmen who use them. Thus the lines of teeth in cabinet rasps, wood rasps, and farriers' rasps, are cut in lines sloping from the left down to the right-hand side; the teeth of rasps for boot- and shoe-last makers and some others are sloped the reverse way; and rasps for gun-stockers and saddle-tree makers are cut in circular lines or crescent form. These directions are quite immaterial; but it is important that every succeeding tooth should cross its predecessor, or be intermediate to the two before it; as, if the teeth followed one another in right lines, they would produce furrows in the work, and not comparatively smooth surfaces.

1589.



In cutting files and rasps they almost always become more or less bent, and there would be danger of breaking them if they were set straight while cold; they are consequently straightened while they are at the red heat, immediately prior to their being hardened and tempered. Previously to their being hardened, the files are drawn through beer grounds, yeast, or other sticky matter, and then through common salt, mixed with cow's hoof previously roasted and pounded, which serve as a defence to protect the delicate teeth of the file from the direct action of the fire. The compound likewise serves as an index of the temperature, as on the fusion of the salt the hardening heat is attained; the defense also lessens the disposition of the files to crack or clink on being immersed in the water. The file, after having been smeared over as above, is gradually heated to a dull red, and is then mostly straightened with a leaden hammer on two small blocks, also of lead; the temperature of the file is afterward increased until the salt on its surface just fuses, when the file is immediately dipped in water. The file is immersed quickly or slowly, vertically or obliquely, according to its form; that mode being adopted for each variety of file which is considered best calculated to keep it straight. It is well known that from the unsymmetrical section of the half-round file, it is disposed, on being immersed, to become hollow or bowed on the convex side, and this tendency is compensated for by curving the file while soft in a nearly equal degree in the reverse direction. It nevertheless commonly happens that with every precaution the file becomes more or less bent in hardening; and if so, it is straightened by pressure, either before it is quite cold, or else after it has been partially reheated. The pressure is variously applied: sometimes by passing one end of the file under a hook, supporting the centre on a prop of lead, and bearing down the opposite end of the file; at other times by using a support at each end, and applying pressure in the middle, by means of a lever, the end of which is hooked to the bench. Large files are always straightened before they are quite cooled after the hardening, and while the central part retains a considerable degree of heat. When straightened, the file is cooled in oil, which saves the teeth from becoming rusty.

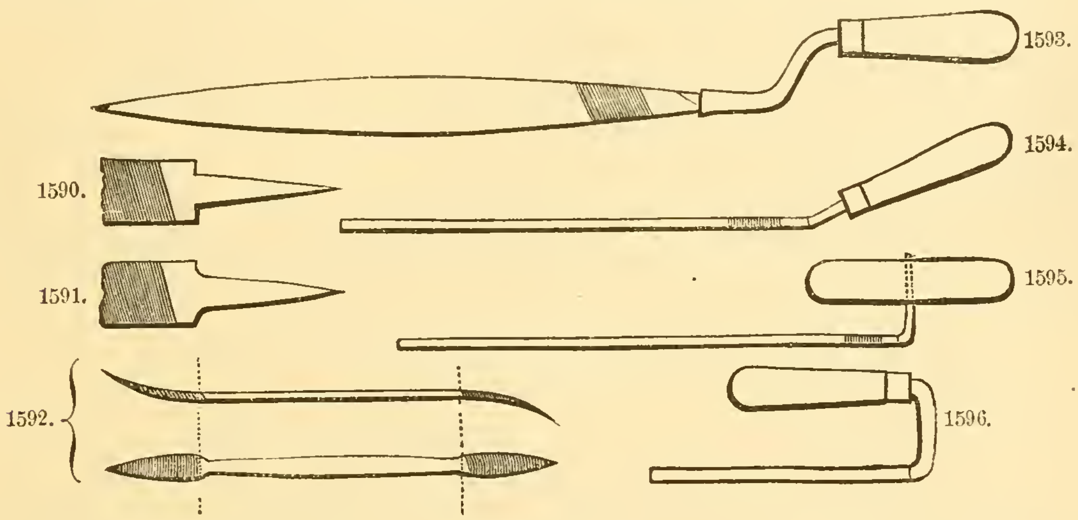
The tangs are now softened to prevent their fracture; this is done either by grasping the tang in a pair of heated tongs, or by means of a bath of lead contained in an iron vessel with a perforated cover, through the holes in which the tangs are immersed in the melted lead that is heated to the

proper degree. The tang is afterward cooled in oil; and when the file has been wiped and the teeth brushed clean, it is considered fit for use.

The superiority of the file will be found to depend on four points: the primary excellence of the steel, the proper forging and annealing without excess of heat, the correct formation of the teeth, and the success of the hardening.

*Increment-Cut File.*—This name is given to a machine-cut file manufactured by the Nicholson File Company, the rows of teeth of which are spaced progressively wider, from the point toward the middle of the file, by regular increments of spacing; and progressively narrower, from the middle toward the heel, by regular decrements of spacing. This general law of the spacing of the teeth is modified by introducing, as they are cut, an element of controllable irregularity as to their spacing; which irregularity is confined within maximum and minimum limits, but is not a regular progressive increment or decrement. The teeth are arranged so that the successive rows shall not be exactly parallel, but cut slightly angularly with respect to each other, the angle of inclination being reversed during the operation of cutting, as necessity requires. Files possessing the characteristics above mentioned do not produce channels or furrows in the work, but effect a *shearing cut*, for the reason that no two successive teeth in any longitudinal row of a cross-cut file are in alignment; the file is, it is claimed, thereby able to cut more smoothly and more rapidly, and possesses greater endurance as a tool for dressing metal than files not so cut.

*Means of Grasping the File.*—In general, the end of the file is forged simply into a taper tang or spike, for the purpose of fixing it in its wooden handle; but wide files require that the tang should be reduced in width, either as in Fig. 1590 or 1591. The former mode, especially in large files, is




apt to cripple the steel and dispose the tang to break off, after which the file is nearly useless. The curvilinear tang, Fig. 1591, is far less open to this objection. Some workmen make the tangs of large files red-hot, that they may burn their own recesses in the handles; but this is objectionable, as the charred wood is apt to crumble away and release the file. It is more proper to form the cavity in the handle with coarse floats made for the purpose.

In driving large files into their handles, it is usual to place the point of the file in the hollow behind the chaps of the tail-vise, and to drive on the handle with a mallet or hammer. Smaller files are fixed obliquely in the jaws of the vise, between clamps of sheet brass, to prevent the teeth either of the vise or file from being injured, and the handle is then driven on.

In the double-edged rifflers, or bent files, Fig. 1592, and in some other files, there is a plain part in the middle, fulfilling the office of a handle; and in several of the files and rasps made for dentists, farriers, and shoemakers, the tool is also double, but without any intermediate plain part, so that the one end serves as the handle for the other.

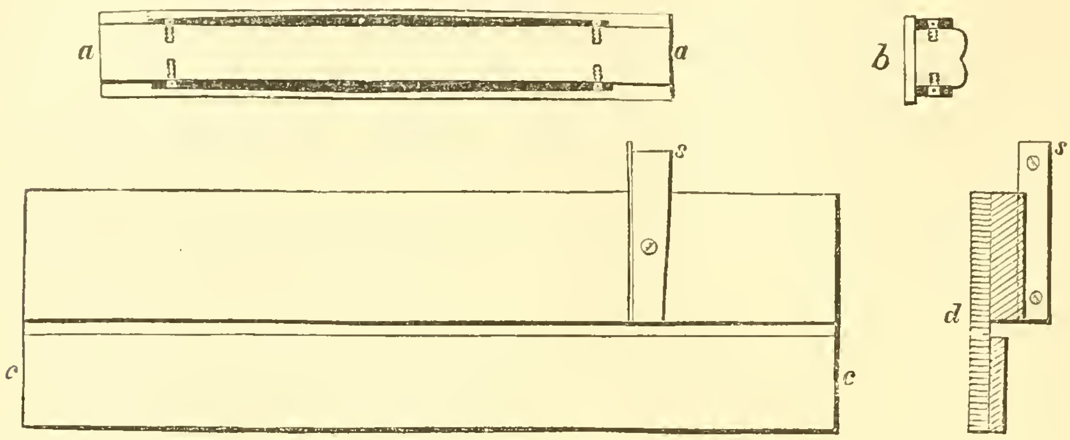
In general, the length of the file exceeds that of the object filed, but in filing large surfaces it becomes occasionally necessary to attach cranked handles to the large files or rubbers, as in Fig. 1593, in order to raise the hand above the plane of the work. Sometimes the end of the file is simply inclined, as in Fig. 1594, or bent at right angles, as in Fig. 1595, for the attachment of the wooden handles represented; but the last two modes prevent the second side of the file from being used, until the tang is bent the reverse way. The necessity for bending the file is avoided by employing as a handle a piece of round iron, five-eighths or three-fourths of an inch in diameter, bent into the semicircular form as an arch, the one extremity (or abutment) of which is filed with a taper groove to fit the tang of the file, while the opposite end is flat, and rests upon the teeth; in this manner both sides of the file may be used without any preparation.

Fig. 1596 represents, in profile, a broad and short rasp with fine teeth, used by iron-founders in smoothing off loam moulds for iron castings; this is mostly used on large surfaces, to which the ordinary handle would be inapplicable, and the same kind of tool when made with coarser teeth will be recognized as the baker's rasp.

Cabinet-makers sometimes fix the file to a block of wood to serve for the grasp, and use it as a plane. Thus mounted, the file may also be very conveniently used on a shooting-board, in filing the edges of plates to be inlaid. Fig. 1597 represents a very good arrangement of this hind. *a a* is the plan, *b* the section of the file stock; *c c* is the plan of the shooting-board, and *d* its section. Two files (that are represented black) are screwed against the sides of a straight bar of wood, which has

also a wooden sole or bottom plate, that projects beyond the files, so that the smooth edge of the sole may touch the shooting-board instead of the file-teeth. The shooting-board is made in three pieces, so as to form a groove to receive the file-dust, which would otherwise get under the stock of the file. The shooting-board has also a wooden stop *s*, faced with steel, that is wedged and screwed

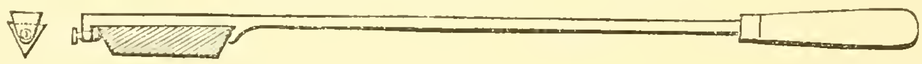
1597.




into a groove made across the top piece; and the stop, being exactly at right angles, serves also to assist in squaring the edges of plates or the ends of long bars, with accuracy and expedition.

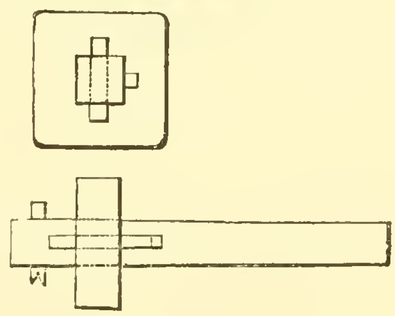
Short pieces of files (or tools as nearly allied to saws) are occasionally fixed in the ends of wooden stocks, in all other respects like the routing gauges of carpenters, as seen in two views in Fig. 1598. The coopers' *croze* is a tool of this description.

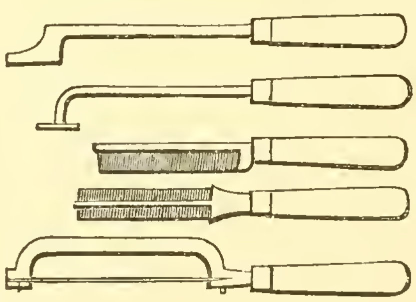
Files intended for finishing the grooves in the edges of slides are sometimes made of short pieces of steel of the proper section (see Fig. 1599), cut on the surfaces with file-teeth, and attached in various ways to slender rods or wires, serving as the handles, and extending beyond the ends of the slides; or the handle is at right angles to the file, and formed at the end, as a staple, to clip the ends of the short file, as in reaching the bottom of a cavity. Files intended to reach to the bottom



1599.

1598.





1600. 1601. 1602. 1603. 1604.

of shallow cavities are also constructed as in Figs. 1600 and 1601; or sometimes an inch or more of the end of an ordinary file is bent some 20° or 30°, that the remainder may clear the margin of the recess.

To stiffen slender files, they are occasionally made with tin or brass backs, as in Figs. 1602 and 1603; such are called dovetail files. Thin equaling files are sometimes grasped in a brass frame, Fig. 1604, exactly like that used for a metal frame-saw.

See "A Treatise on Files and Rasps," Nicholson File Company, Providence, 1878, from which many extracts and illustrations are embodied in the foregoing article.

FILING. The excellence of a piece of work operated upon by a file is only limited by the skill of the operator; for since a file can be made of any shape and size, and since the quantity of material it will cut away and the location of the same may be varied at will, it is evident that it is possible to perform with the file every operation that can be performed with steel tools. The legitimate use of the file may be classed under four headings: first, for the removal of a surplusage of metal; second, to correct errors in the truth of work which has been operated upon by such machine tools as the planer and shaper; third, for the production of small intricate or irregular forms; and fourth, to fit work together more accurately than can be done by other means.

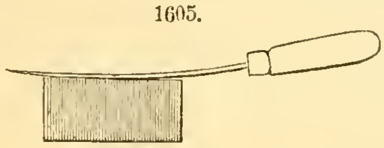
Work to be filed should be held with the surface to be operated upon lying face upward and *horizontally;* and the general rule for the height of the work above the ground is, that the surface to be filed should be nearly level with the elbow-joint of the workman. Some latitude is, however, required in respect to the magnitude of the works, as when they are massive, and much is to be filed off from them, it is desirable that the work should be a trifle lower than the elbow; when the work is minute and delicate, it should be somewhat higher, so that the eye may be the better able to add its scrutiny to that of the sense of feeling of the hand, upon which principally the successful practice depends.

Since the teeth of a file are unequal in height, and the form of the file warps in the hardening

process, it is evident that, even supposing the operator to be able to move the file in a straight line, the surface filed would not be straight. Hence a file to act upon flat surfaces should be thickest in the middle, and thinner at each end of its length. This gives to the surface of the teeth a curve or sweep in the length of the file; and if the file should warp, the effect is merely to lessen the sweep on one side and increase it on the other. This is of but little consequence, since, by altering the height of the respective ends of the file, any part of the same may be brought into contact with the work. Furthermore, the file can be so applied as to act upon any high spot or part of the surface without cutting the surrounding surface. It is of no consequence if one side of the file possesses more sweep than the other, because, so long as it is moved in a straight line, the teeth performing duty will cut a straight surface if passed clear across the work. The curve of the file, however, is usually about sufficient to compensate for any variation of the stroke from a horizontal plane. The level of the teeth crosswise of the file may be either flat or a little rounding, the latter being preferable; but in no case should it be (for flat surfaces) hollow, because in that case the edges would cut grooves in the work. For convex surfaces a flat file is usually employed; but for concave surfaces the file must be given a convexity greater than the concavity of the work, so that any desired part of the file may be brought into contact with the work, notwithstanding a slight irregularity in the curve of the file.

In Fig. 1605 is shown the shape of file desirable for a concave surface. The difficulty experienced in filing a narrow surface flat is explained by reference to Figs. 1606, 1607, and 1608. The file, held

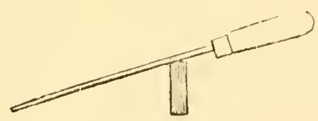
1605.



1606.


1607.

1608.



in the two hands upon the narrow work, may be viewed as a double-ended lever, or as a scale-beam supported on a prop; and the variation in distance of the hands from the work or prop gives a disposition to rotate the file upon the work, which is only counteracted by habit or experience.

Assuming, for the moment, that in the three diagrams the vertical pressure of the right hand at $r$ and of the left at $l$ is in all cases alike, in Fig. 1606, or the beginning of the stroke, the right hand would, from acting at the longer end of the lever, become depressed; in Fig. 1607, or the central position, the hands would be in equilibrium and the file horizontal; and in Fig. 1608, or the end of the stroke, the left hand would preponderate; the three positions would inevitably make the work round, in place of leaving it plane or flat. It is true the diagrams are extravagant, but this rolling action of the file upon the work is in most cases to be observed in the beginner; and it is only by much practice that it can be counteracted, which is done by maintaining a pressure at and upon each end of the file so proportioned that, the teeth performing duty forming a fulcrum, the pressure on each end of the file decreases in proportion to its distance from that fulcrum.

In using the file for large work, such as is common in a general machine shop, it should be fixed firmly in its handle, which should be placed truly upon the file. The butt end of the handle should press firmly against the palm of the hand, the forefinger being placed beneath the file-handle. To take off a quantity of metal, the operator should stand sufficiently far from the work to be able to bend the body and place its weight upon the file during the forward stroke. During the back stroke the pressure upon the file-teeth should be removed, otherwise the teeth of the file become rapidly worn. A new file should never be used upon a very narrow surface, because the teeth, from their keenness, sink so deeply in the metal and take so firm a grip that they receive a strain from the cut sufficient to break them off. The most economical way to employ a file is to use it upon brass first, because brass requires a keen file. After the tool has become impaired for brass work, it is still good for use on cast-iron, wrought-iron, or steel. If the cuttings jam in the file (this is called *pinning*), they should be removed with a file-card; or if too fast to be taken off by that tool, a piece of sheet copper or brass about three-eighths of an inch wide, $2\frac{1}{2}$ inches long, and one-thirty-second of an inch thick, should have one end hammered thin, and this thinned edge should be passed across the file. It should be pressed firmly to and moved along the rows of teeth, in order that it may become serrated and force out the pins. To prevent pinning, the file-teeth may have soft chalk rubbed over them, which will prevent the filings from getting locked in the teeth. After every few strokes of the file the hand should be brushed over it, and the file should be lightly tapped against the bench or vise-box, when the loose filings will fall out. When, however, the file requires rechalking, which will easily become apparent, the use of the file-card may precede the application of the chalk. This chalking process is especially necessary during the finishing, as the pins are sure to scratch the work. In using rough or bastard files to remove a quantity of metal, it is well so to regulate the motion of the file that the file-marks cross and recross each other, which not only tends to keep the filing true, but increases the efficiency of the operation. It is to be especially noted, however, that in giving the file lateral side motion during each stroke, it will pin less if that motion takes place from right to left, and this in consequence of the cut of the file. The serrations forming the teeth cross each other diagonally. The first series are nearest to the front end of the file on the left-hand side, while the last and therefore the deepest serrations, forming on the finished file the rows of the teeth, stand

diagonally, being nearest to the file-handle on the left-hand side. Therefore, by giving to the file stroke a certain amount of lateral side motion, the cutting duty is performed by the teeth more in a direction parallel to the rows of the file-teeth, and the cross-filing, as the forward motion of the file is termed, partakes slightly of the nature of draw-filing.

Work requiring to be finely finished should be operated upon by the second-cut, smooth, and superfine smooth files, the cross-filing being succeeded by draw-filing.

The object of draw-filing is two-fold: first, the file can be held more steadily, and can therefore be applied to any circumscribed part of the work exclusively, as is necessary in truing work; and secondly, the teeth cut finer and smoother. Hence it is that draw-filing is necessary to the production of fine and accurate work. In draw-filing to obtain accuracy, the high spots or parts of the file should be selected to remove the places which the test-marks upon the work indicate as requiring to be filed, and the file-marks should be kept as straight as possible. But in draw-filing to finish finely, the file-marks may be made to cross each other at frequent intervals. In either case the stroke of the file should be a short one, in no case exceeding about 4 inches, as longer ones produce pinning and the attendant evil, scratches. A worn file, either smooth, superfine smooth, or dead smooth, will finish finer than a new one; and better results will be obtained by finishing the work crosswise of the grain than on a line with it, because any inequality in the metal will usually run with the grain, and the file-teeth will cut the softer parts of the metal better when following their length than when merely crossing them. For the very finest of work, the Groubet files should be used, as they are the finest-cut files made, besides being unusually true to shape.

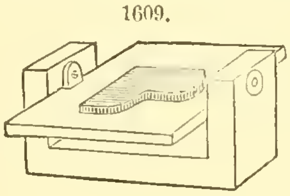
Filed work is usually polished by the application of emery paper. With emery paper, as with files, the more used it is, the better it will polish, because it becomes coated with a glazed surface composed of particles of the metal it has been rubbing, and all metals polish better by the application of such a surface than by that of any other.

Half-round files should be used, during both the roughing-out and finishing processes, with a side or lateral sweep; otherwise they are apt to produce waves in the work.

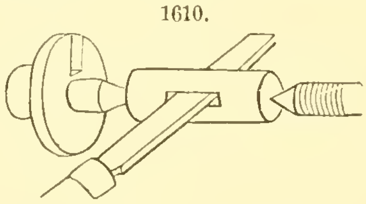
In filing out keyways, it often becomes necessary to use the most rounded or curved face at the end of the file only, so that, the operation being out of sight, the workman may insure that the file has contact with the work in such places only as is necessary. A similar method is also pursued in facing outside surfaces very true; and if great care is taken and very fine files are used, surfaces equal to the finest scraped ones may be produced by the file.

Files are often employed for the finishing of work turned in the lathe. For this purpose fine files

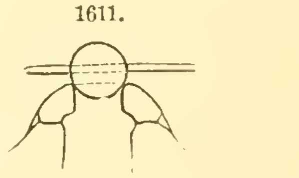
1609.



1610.



1611.



only should be used, and the amount of the duty should be kept as small as possible, because the file is apt to cut more readily into the softer parts of the metal, and hence to make the work out of round.

The work, when small, is almost invariably held on the filing-block with the left hand, occasionally through the intervention of a hand-vise, Fig. 1612. In this case the two hands act in concert, the right in moving the file, the left in adjusting the position of the work, until the workman is conscious of the agreement in position of the two parts. Sometimes indeed the partial rotation of the work, in order to adapt it to the file, is especially provided for, so as to compensate for the accidental swaying of the file; such is the case in the various kinds of *swing tools*, used by watchmakers in filing and polishing small flat works. A similar end is more rarely obtained, on a larger scale, when the file is required to be held in both hands. For example, *filing-boards*, resembling Fig. 1609, and upon which the work is placed, have been made to move on two pivots, somewhat as a gun moves on its trunnions; consequently the work, when laid upon the swinging board, assumes the same angle as that at which the file may at the moment be held.

A more common case is to be seen in filing a rectangular mortise through a cylindrical spindle, as in Fig. 1610. The hole is commenced by drilling three or four holes, which are thrown into one by a cross-cut chisel or small round file; and the work, when nearly completed, is suspended between the centres of the lathe, so that it may freely assume the inclination of the file. At other times, the cylinder is laid in the interval between the edges of the jaws of the vise, that are opened as much as two-thirds the diameter of the object, which then similarly rotates on the supporting edges; this mode is shown in Fig. 1611. These three applications are objectionable in some instances, as the file is left too much at liberty, and the work is liable to be filed hollow instead of flat, especially if the file be rounding, because the unstable position of the work prevents the file from being constrained to act on any particular spot that may require to be reduced.

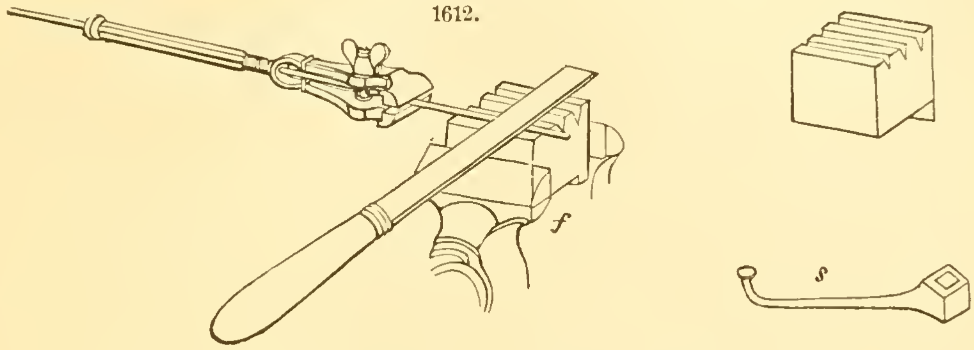
A great number of small works are more conveniently filed while they are held with the left hand, the file being then managed exclusively with the right; this enables the artisan more easily to judge of the position of the file. In such cases, a piece of wood, *f*, Fig. 1612, called a *filing-block*, is fixed in the table or tail-vise. (See VISE.)

Numerous flat works are too large, thin, and irregular in their superficies to admit of being fixed in the various kinds of bench-vises, as there would be risk of bending such thin pieces by the pressure of the vise applied against the edges of the work. The largest flat works are simply laid on the naked surface of the work-bench, and temporarily held by half a dozen or more pins or

nails driven into the bench. The pins should be as close to the margin as possible, and yet below the surface of the work. For thin flat works of smaller size, the filing-board, Fig. 1613, is a convenient appendage; it measures 6 or 8 inches square, and has a stout rib on the under side, by which it is fixed in the vise. In filing thin flat works, such as the thin handles or scales of penknives and razors, and the thin steel plates used in pocket-knives, cutlers generally resort to the contrivance represented in Fig. 1614, known as a *flatting-vise.* One face of the small filing-block *f*, Fig. 1612, is also used for very small thin works, which are prevented from slipping from the file by the wooden ledge, or by pins driven in. In many instances, also, thin works are held upon a piece of cork, beneath which is glued a square piece of wood, that the cork may be held in the vise without being compressed. The elasticity of the cork allows the work to become somewhat imbedded by the pressure of the file, between which and the surface-friction it is sufficiently secured for the purpose without pins.

Before any effective progress can be made in filing flat works, the operator must be provided with

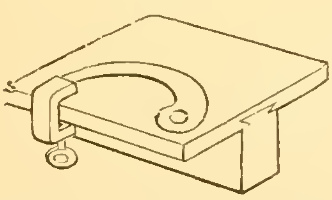
1612.



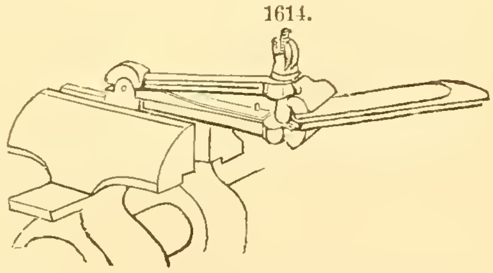

the means of testing the progressive advance of the work; he should therefore possess a *true straight-edge* and a true surface-plate. The straight-edges used by smiths are generally of steel, and although they have sometimes a nearly acute edge, it is much more usual to give them moderate width; thus, in steel straight-edges from 1 to 4 feet in length, the width of the edge is from one-sixteenth to one-fourth of an inch; and in cast-iron straight-edges from 6 to 9 feet in length, the width is usually 2 to 3 inches. The straight-edge is used for trying the surface that is under correction, along its four margins, across its two diagonals, and at various intermediate parts, which respective lines, if all exact, denote the surface to be correct. But the straight-edge alone is a tedious and scarcely sufficient test; and when great accuracy is desired, it is almost imperative to have at least one very exact plane metallic surface or surface-plate, by which the general condition of the surface under formation may be more quickly and accurately tested at one operation; and to avoid confusion of terms, it is proposed in all cases, when speaking of the instrument, to employ the appellation *planometer*, which is exact and distinctive. (See PLANOMETERS.)

The flat piece of cast-iron intended to be operated upon having been chipped all over, a coarse hand-file, of as large dimensions as the operator can safely manage, is selected. In the commencement the rough edges or ridges left by the chipping chisel are leveled, those parts however being principally filed that appear from the straight-edge to be too high. The strokes of the file are directed sometimes square across as on a fixed line, or obliquely in both directions alternately; at other times the file is traversed a little to the right or left during the stroke, so as to make it apply

1613.



1614.



to a portion of the work exceeding the width of the file. These changes in the applications of the file are almost constantly given, in order that the various positions may cross each other in all possible directions, and prevent the formation of partial hollows. The work is tried at short intervals with the straight-edge; and the eye, directed on a level with the work to be tested, readily perceives the points that are most prominent. After the rough errors have been partially removed, the work is taken from the vise and struck edgewise upon the bench to shake off any loose filings, and it is then inverted on the planometer, which should be fully as large as or larger than the work. As, however, it cannot be told by the eye which points of the work touch the planometer, this instrument is coated all over with some coloring matter, such as pulverized red chalk mixed with a little oil, and then the touching places become colored. The work is slightly rubbed on the surface-plate, and then picks up at its highest points some of the red matter; it is refixed in the vise, and the file is principally used in the vicinity of the colored parts, with the occasional test of the straight-edge, and after a short period the work is again tried on the planometer. This process is continually repeated, and if watchfully performed it will be found that the points of contact will become gradually increased.

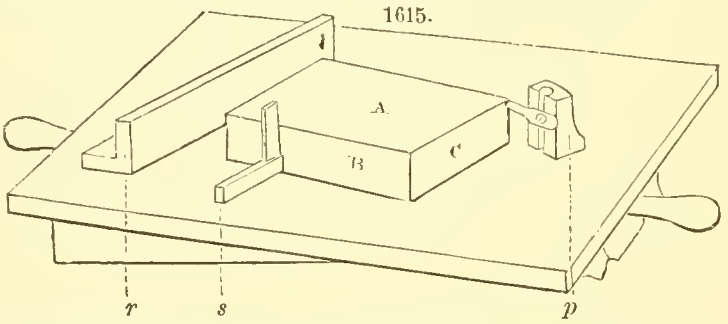
The grooved or roughing-out cutter is employed in the commencement, because it more rapidly penetrates the work, and a few strokes are given to crop off the highest points of the surface; the furrows made by the serrated cutter are then nearly removed with the file, which acts more expeditiously although less exactly than the plane, and in this manner the grooved plane-iron and the coarse file are alternately used. In the absence of the planometer, the metal plane assumes a greatly increased degree of importance. As the work becomes gradually nearer to truth, the grooved cutter is exchanged for that with a continuous or smooth edge. A second-cut or bastard file is also selected, and the same alternation of planing and filing is persevered in, the plane serving as it were to direct the file, until it is found that the plane-iron acts too vigorously, as it is scarcely satisfied with merely scraping over the surface of the cast-iron, but when it acts removes a shaving having a nearly measurable thickness, and therefore, although the hand-plane may not injure the general truth of the surface, it will prevent the work from being so delicately acted upon as the continuance of the process now demands; a smoother hand-file is consequently alone employed in furthering the work.

It is now often usual to discontinue the use of the file, and to prosecute the work with a scraper, which, having a sharp *edge*, instead of a broad and abrading *surface*, may be made to act with far more decision on any, even the most minute, spot or point. (See Scraper.) The scraper, however, is not intended to remove a quantity of metal; hence even work requiring to be finished by the scraper should be first made true by smooth filing, especially if the planing or milling-tool marks are left upon the work, for in that case the scraper edge is apt to follow those marks instead of cutting smoothly as it should do.

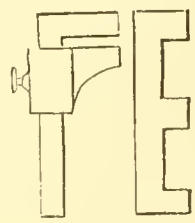
The former instructions have been restricted to the supposition that only one of the superficies of the work was required to be made plane or flat; but it frequently happens in rectangular works, such as the piece *A B C*, Fig. 1615, that all six surfaces, namely, the top and bottom *A a*, the two sides *B b*, and the two ends *C c*, all require to be corrected and made in rectangular arrangement (the surfaces *a b c* being necessarily concealed from view); and therefore some particulars of the ordinary method of producing these six surfaces will be added.

The general rule is first to file up the two largest and principal faces *A* and *a*, and afterward the smaller faces or edges *B b* and *C c*. The principal faces *A a*, especially when the pieces are thin, must be proceeded with for a period simultaneously, because of the liability of all materials to spring and alter in their form with the progressive removal of their substance; and on this account

1615.




1616. 1617.



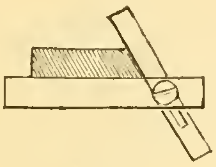
the work, whether thick or thin, is frequently prepared to a certain stage at *every* part, before the final correction is attempted of any *one* part. The straight-edge and surface-plate are required to prove that each of the faces *A* and *a* is a plane surface, and the calipers or a similar gauge is also needful to prove them to be in parallelism. Calipers, unless provided with set-screws, are very liable to be accidentally shifted, and it is needful to use them with caution; otherwise their elasticity, arising from the length of their legs, is apt to deceive. There are gauges, such as Fig. 1616, with short parallel jaws that open as on a slide, and are fixed by a side screw; and a still more simple and very safe plan is to file two rectangular notches in a piece of sheet-iron or steel, as in Fig. 1617, the one notch exactly of the finished thickness the work is required to possess, the other a little larger to serve as the coarse or preliminary gauge. (See Calipers, and Gauges.)

Sometimes, the one face of the work, or *A*, having been filed moderately flat, a line is scored around the four sides of the work with a metal marking-gauge, the same in principle as the marking-gauge of the joiner. At other times the corrected face *A* is laid on a planometer larger than the work, and the marginal line is scribed on the four edges by a scribing-point *p*, Fig. 1619, projecting from the sides of a little metal pedestal that bears truly on the surface-plate. Chamfers or beveled edges are then filed around the four edges of the face *a*, exactly to terminate on the scribed lines: the central part of *a* can be reduced with but little watchfulness, until the marginal chamfers are nearly obliterated. This saves much of the time that would be otherwise required for investigating the progress made; but toward the last the calipers and planometer must be carefully and continually used, to assist in rendering *A* and *a* at the same time parallel and plane surfaces. The two principal edges *B b* are then filed under the guidance of a square. The one arm of the square is applied on *A* or *a* at pleasure, as in joinery work; or if the square have a thick back, it may be placed on the planometer, as at *s*, Fig. 1615; if preferred, the work may be supported on its edge *B* upon the planometer, and the back square also applied, as at *s*, in which case the entire length of the blade of the square comes into operation, and the irregularities of the plane *B* are at the same time rendered obvious by the planometer. Another very convenient test has been recommended for this part of the work, namely, a stout bar, such as *r*, Fig. 1615, the two neighboring sides of which have been made quite flat and also square with each other. When the work and trial-bar are both laid down, the one side of the bar presents a truly perpendicular face, which may, by the interven-

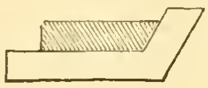
tion of coloring matter, be made to record on the work itself the points in which $B$ differs from a rectangular and vertical plane. When the edge $B$ has been rendered plane and square, the opposite edge $b$ may in its turn be marked either with the gauge or scribing-point at pleasure; the four edges of $b$ may be then chamfered, and the entire surface of $b$ is afterward corrected (as in producing the second face $a$), under the guidance of the square, calipers, rectangular bar, and surface-plate, or some of these tests. The ends $C\ c$ now claim attention, and the marginal line is scribed around these by the aid of the back square alone; but the general method so closely resembles that just described as not to call for additional particulars.

Should one edge of the work be inclined or beveled, as in the three following figures, in which the works are shaded to distinguish them from the tools, the rectangular parts are always first wrought,

1618.

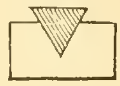


1619.

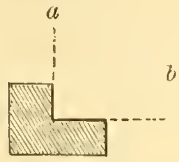


1620.

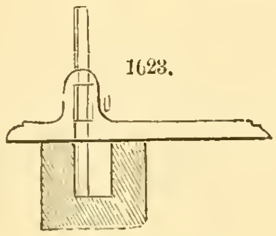
1621.



1622.

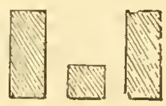



1623.



1624.

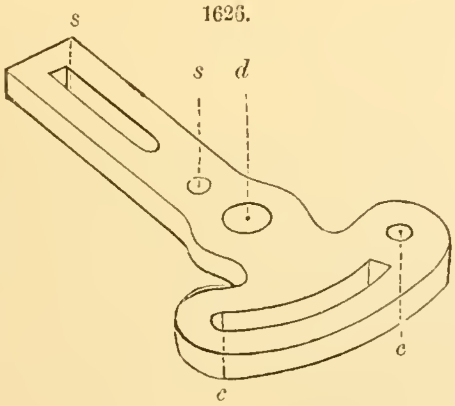
1625.



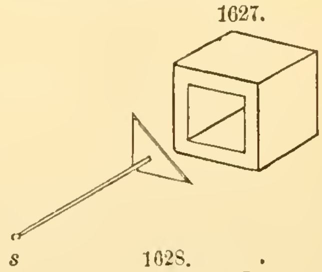
and then the beveled edges, the angles being denoted by a bevel instead of a square; either with a bevel having a movable blade, Fig. 1618, or by a beveled templet made of sheet metal, as in Figs. 1619 or 1620, which latter cannot get misadjusted. The beveled edge of the work is also applied if possible on the planometer; in fact, the planometer and bevel are conjointly used as the tests. Beveled works are either held in the vise by aid of the chamfer-clamps, or they are laid in wooden troughs, with grooves so inclined that the edge to be filed is placed horizontally. Triangular bars of equilateral section are thus filed in troughs, the sides of which meet at an angle of 60°, as in Fig. 1621.

The succeeding examples of works with many plane surfaces are objects with rebates and grooves, as represented in Figs. 1622 to 1625. Pieces of the sections, Figs. 1622 and 1623, supposing them to be short, would in general be formed in the solid, either from forgings or castings, as the case might be; the four exterior and more accessible faces would be filed up square and true, and afterward the interior faces, with a due regard to their parallelism with the neighboring parts, after the mode already set forth. The safe edge of the file is now indispensable; as in filing the face $b$, the safe edge of the file is allowed to rub against the face $a$ of the work, which therefore serves for its guidance, and in filing the face $a$ the side $b$ becomes the guide for the file. The groove in Fig. 1623 requires a safe-edge square file. When, however, pieces of these sections, but of greater lengths, have to be produced by means of the file alone, it is more usual to make them in two or three pieces

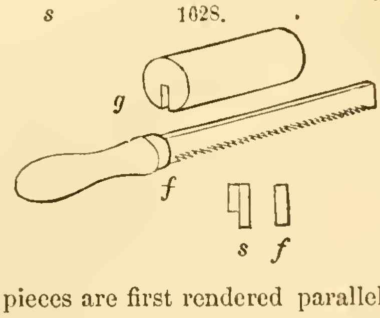
1626.




1627.




1628.




respectively, as shown detached in Figs. 1624 and 1625; which pieces are first rendered parallel on their several edges, and are then united by screws and steady-pins.

In works of these kinds, which have rebates, grooves, internal angles, or cavities, the square with a sliding blade, shown in Fig. 1623, is very useful, as the blade serves as a gauge for depth, besides acting as a square, the one arm of which may be made of the precise measure of the edge to be tried. This instrument is often called a turning-square, as it is particularly useful for measuring the depth of boxes and other hollowed works turned in the lathe.

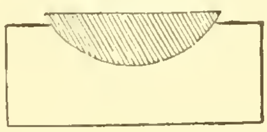
In making straight mortises, as at $s\ s$, Fig. 1626, unless the groove is roughly formed at the forge or in the foundry, it is usual to drill holes nearly as large as the width of the mortise, and in a straight line; the holes are then thrown into one another by a round file or a cross-cutting chisel,

and the sides of the mortise are afterward filed square and true. For a curved mortise, *c c*, the mode is just the same, with the exception that the holes are made on a curved line; and that, instead of a flat file being used throughout, a half-round or a crossing file is used for the concave side of the mortise. Short rectangular mortises, or those which may be rather considered to be square holes, as in Fig. 1627, would, if large, be prepared by forging or casting the material into the form; and then, the six exterior faces having been corrected, the aperture would be filed on all sides under guidance of some of the various tests before referred to. In such a case it is convenient to employ a small square *s*, in the form of a right-angled triangle, to which is attached a wire that may serve as a handle, whereby the square may be applied at any part within the mortise without the sight of the workman being intercepted by his own fingers. Sometimes also a cubical block, filed truly on four of its faces to the exact dimensions of the aperture, is used as a measure of the parallelism and flatness of the four interior faces.

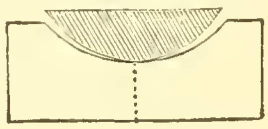
In making by hand the keyways in the round holes of wheels, it is to be observed that it is common to turn a cylindrical plug exactly to fill the hole, and to make a notch in the plug as wide as the intended keyway and parallel with the axis; the plug is shown at *g*, Fig. 1628. A piece of steel *f* is then filed parallel, and exactly to fit the notch, and its edge is cut as a file, and used as such within the guide-block, the latter being at the time inserted in the hole of the wheel. In this case the block becomes the director of the file, and the notches in any number of wheels are made both parallel and axial. The only precaution that remains to be observed is in regard to the depth of the notches, and this is not always important; the depth may, however, be readily determined by making the grooves at first a little shallower than their intended depth, and then, the plug having been removed from the hole, a stop is attached to the side of the file, parallel with its edge, as at *s*, to prevent its penetrating beyond the assigned depth. (See Keys and Keyways.)

The manipulation of the file upon curvilinear works is entirely different from that required to pro-

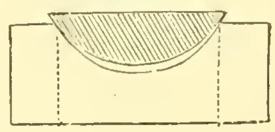
1629.



1630.

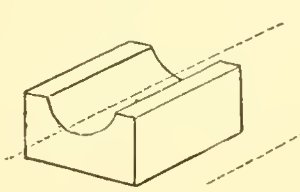


1631.

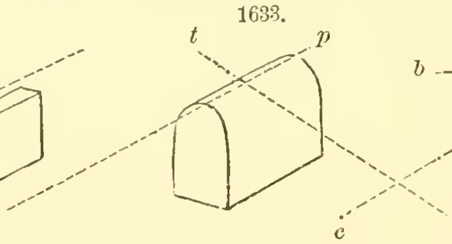


duce a plane surface, in which latter case the work is held at rest and the hands are moved as steadily as possible in right lines; but in filing curved works an incessant change of direction is important, and, so far as practicable, either the file or the work is made to rotate about the axis of the curve to be produced. A semicircular groove of half an inch radius, as in Fig. 1629, would be most easily filed with a round file of nearly the same curvature, and the correspondence between the file and work, and consequently of their axes likewise, would render the matter very easy; but the file, from the irregularity of its teeth, would leave ridges in the work, unless in every stroke it were also twisted to and fro axially by the motion of the wrist, and occasionally in the reverse direction,

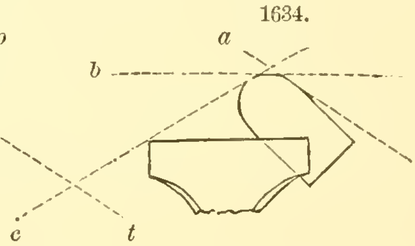
1632.




1633.




1634.




so that the furrows made by the teeth might cross each other. If the groove to be filed had a diameter of three or four inches, although the file might be selected to correspond in curvature with the groove, as it would not embrace the entire hollow, the twisting and traversing of the file would be imperative in order to arrive at all parts of the work. Under ordinary circumstances it is certainly best that the curvature of the file and work should agree as nearly as possible; but it is obvious that the file, if more convex than the work, can only touch the latter at one part, as at *a*, Fig. 1630; whereas, if the file is less convex or flatter than the work, it will act at two places, as at *b b*, Fig. 1631. Cutlers, in filing out the bows of scissors, always avail themselves of this circumstance, and until nearly the conclusion use files flatter or less convex than the work.

In filing concave works, there is but little choice of position, as the file is always parallel with the axis of the curve, as in the dotted line in Fig. 1632; but in convex works, such as Fig. 1633, the file may be applied either parallel with the axis, as at *p p*, or transversely thereto, as at *t t*. In general, however, the work would be fixed obliquely, as in Fig. 1634, and the file would be first used transversely for some one or two strokes, at an inclination of about 30° with the horizontal line, as at *a*, so as nearly to agree with the straight side of the object; the file would be successively raised to the horizontal, and depressed in the same degree on the other side; in fact, proceeding through the positions *a b c*, Fig. 1634, at some eight or ten intervals, which would tend to make as many insignificant ridges upon the work. The ridges would be then melted together by swinging the hands from the position *a* to *c* in every stroke, to be repeated a few times; but as the entire semicircle could not be embraced at one stroke, the work would be refixed in two or more positions, so as to divide the operation into about three stages. A more exact although less energetic method would be to place the file parallel with the axis, as on *p p*, Fig. 1633, and to sweep round the curve principally by the twisting motion of the wrist. A third mode, frequently adopted in such small pieces

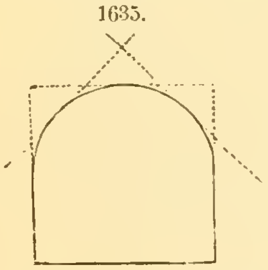
as can be held upon the filing-block with the hand-vise, is to swing the work upon its axis, and to use the file with the right hand, as if on a flat surface.

Some works are curvilinear in both directions, such as curved arms and levers with rounded edges; many of these kinds are completed by draw-filing them, or rubbing the file sideways or laterally around the curve, instead of longitudinally as usual. The great majority of curved works are moulded and formed *prior* to the application of the file, which is then principally used to smooth and brighten them. Other works are shaped almost entirely with the file, assisted by outlines drawn on the pieces themselves; and again other works are shaped with the file, under the guidance of templets or pattern-plates of hardened steel. Some observations will be offered on all three of these modes.

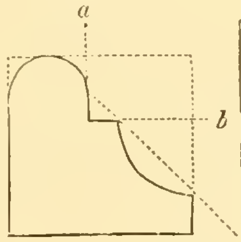
First, in respect to filing up metal works that have been accurately shaped by founding or forging, little or nothing remains to be added, as the only object is to act on every part of curvilinear surfaces in the most expeditious and commodious manner, with the general aim of reducing any trifling errors of form that may already exist in them, and avoiding the introduction of new ones; which circumstances call for the frequent scrutiny of the eye, and an incessant yet judicious variation in the position of the hands.

Secondly, curved works, that are moulded or formed almost entirely with the file, are blocked out square, and the outlines of the curves are drawn on the ends and sides of the pieces, to guide the file in a manner analogous to the routine pursued by carpenters, masons, and other artisans. For instance, to form a bead, as in Fig. 1635, the work is prepared of a nearly rectangular form, and the half circle having been drawn at each end, the angles of the work are coarsely removed at about 45°, making the end a semi-octagon; sometimes the four angles are further reduced, giving to the work eight facets, prior to their being thrown together in making the general curve. If these sides are made with only a very moderate degree of exactness, they will greatly tend to preserve the uniformity of section throughout. Many workmen, when they have removed the two principal angles at 45°, make a chamfer entirely around the semicircle at each end, to guide the file in hastily reducing the principal bulk of the material. It is also desirable that the straight-edge should be frequently applied along the axis of the curve, at various parts, during the progress of the work. Should the entire piece, Fig. 1636, have to be made from a solid block, two cuts, *a* and *b*, made with the saw, would remove the corner. The round part of the bead would be made as before, and previous to filing the hollow it would be chamfered on the line *c*; a half-round file, of less curvature than the hollow itself, would be first sunk in the middle of the chamfer, and the hollow would be deepened and extended sideways, always maintaining an easy curve, until it reached the marginal lines where

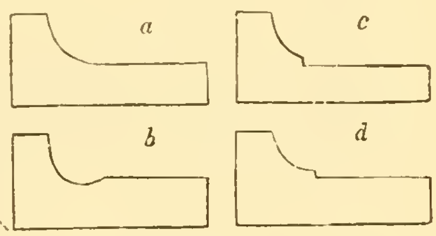
1635.



1636.




1637.



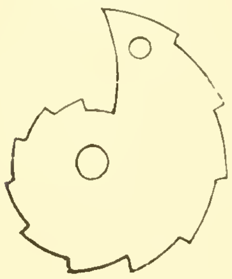

the hollow meets the plane surfaces. Where hollows run on to right lines, as at *a*, Fig. 1637, there is some risk of making a break in the junction, either from the curve sinking below the right line, as at *b*, or from the straight line, as at *c*, advancing too far and breaking in upon the curve. On this account a break or fillet is usually made at the part, as at *d*, or else it is usual primarily to give that form by filing the flat first, and then sinking down the hollow just to meet it, and at the conclusion letting the half-round file run a little way on to the right line. Some, however, prefer the opposite course, or that of sinking the hollow to its full depth, and then filing down the remainder with the flat file; but this mode is certainly attended with more risk.

Thirdly, curved works that are shaped with the file under the guidance of templets or pattern-plates of hardened steel. This mode is much followed in works of two principal kinds, namely, thin works required in great numbers and precisely of one form, and in a variety of works that require to be exactly circular, although they may not admit of being so fashioned in the lathe. Many thin works of the first kind are stamped or punched out of the sheet metals, as for instance the washers for machinery, the links of jointed chains, steel pens, parts of locks for joinery, and numerous other thin works; but many objects of larger kinds, and that are not wanted in such large numbers, are not stamped, but are either cast or cut out with the shears, and afterward filed between templets. The snail-wheel of a striking clock, Fig. 1638, is frequently thus formed by means of a templet; it has an edge formed in twelve steps, arranged spirally, the positions of which determine the number of strokes of the hammer on the bell. In this case, which will serve as a general example, a piece of sheet-steel is cut out, flattened, and smoothed on one side, to receive the drawing of the snail-wheel, and a second piece is also prepared. The two are first drilled together with a central hole, and another hole as distant from the centre as admissible. The two plates are then united by two pins, and the outline of the work having been drawn on one of them, they are next filed in steps carefully to the lines, and square across the edges, and they are afterward hardened and slightly tempered to lessen their liability to fracture on being pinched in the vise. The dozen or more snail-wheels having been cast or cut out of sheet-brass, and flattened with the hammer, two or three at a time are pinched alongside one of the templets, while the two pin-holes are made with the breast-drill or in the lathe, with a drill that exactly fits the holes in the templets. It only remains to place the dozen

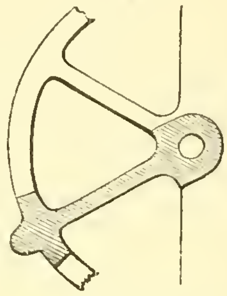
plates between the templets, keeping them in position by two pins extending through the whole number, and then all the notches are filed in the brass plates, until the file *very nearly* touches the steel patterns, as absolute abrasion on the steel itself would greatly injure the files. In this mode the several brass plates become very exact copies of the pattern.

Templets are as much used for setting out and producing series of holes in any special arrangement, as in filing works to any particular form. A complex example of templets being used in this

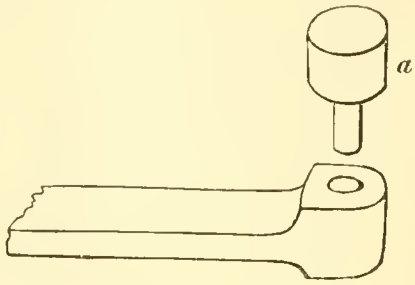
1638.



1639.



1640.




manner is in drilling the side plates of harps intended for the arbors and link-works used in temporarily shortening the strings. The respective positions of the holes in these side plates require a most exact arrangement, any departure from which would prevent that precise shortening of the string required to produce the semitones with critical accuracy, and would also cause an unbearable jar, unless the cranks of the harp were severally in true position, or on the lines of centres, so as firmly to support the tension of the strings under all circumstances.

A different application of templets is sometimes met with in filing up numerous similar parts in the same object, as the arms or crosses for the wheels of clocks and other machines. The exact pattern of one spoke is filed up as a templet, which is shaded in Fig. 1639, and serves for the similar configuration of every spoke; the position of the templet being given by a central pin, aided by any little contrivance which catches into the 3, 4, 5, or 6 equidistant teeth corresponding with the number of arms.

It frequently happens that certain forged, cast, and other works have parts, known as bosses, swells, collars, and knuckles, that are pierced with holes, which require their flat surfaces and also their margins to be made partially or entirely concentric with the holes. When such parts occur as bosses, they often project from a flat surface; and after the central hole is drilled, some of the pin-drills, or analogous tools used in drilling-machines, are employed in finishing the margins.

When the circular margins are discontinuous, files and templets are more or less required. Thus the extremity of a forged arm, such as Fig. 1640, is drilled, and in the configuration of the remaining parts, if but one or two such pieces are to be made, a boss or plug of wood is turned like *a*, that shall fit the hole; the shoulder of the wood is then rubbed with red chalk to mark that part of the surface which is not at right angles to the hole, and the circular edge of the boss serves for the guidance of the file in finishing the exterior margin, visually rather than obstructively, as the wooden boss would be reduced instead of the file being checked. If therefore there were many such objects to be filed, two bosses or templets would be made of hardened steel, and used one at each extremity of the hole, and they would be held in position by grasping the three pieces collectively in the tail-vise. The same general method is very largely and more rigorously followed in making joints or hinges. J. R.

FILTERS. When water containing substances in suspension is passed through a medium provided with fine pores, it is, of course, at least the purer by virtue of the removal of all such matters as are unable to pass through the pores. If this were all filtration accomplished, it would be merely a fine straining process. But all porous substances contain an immense amount of air between their pores, and the water, by being passed through them, is divided into an infinite number of exceedingly small streams, and thus the substances in solution in the water are brought into the closest possible contact with the oxygen of the air, giving rise to a chemical action. This oxidation occurs in ammonia, and the putrescible organic matters which are so dangerous when left in drinking-water.

According to experiments by Dr. Frankland, water containing in solution about 18 grains to the gallon, after filtration through animal charcoal contained 11.6 grains. The organic and other volatile matter contained in the water before filtration amounted to .37 of a grain in a gallon, and after the filtration the amount was .15; that is to say, more than one-half of these matters were removed. After a month this charcoal removed still more organic matter, and also some mineral matters; and even a few months afterward one-half of the organic and volatile matters only remained after filtration. These experiments show that it is not by storing up matters that a filter works—for, in such case, it would soon be choked—but by oxidizing the putrescible substances, the results of which oxidation are afterward found in the shape of nitrites, nitrates, and carbonates. Dr. Frankland states that he passed the water supplied to London by the Grand Junction Company through a thickness of 3 feet of animal charcoal at the rate of 41,000 gallons per square foot per day of 24 hours, under a head of water of 30 feet, the charcoal being in granules like coarse sand. Even at the above high rate more than half the organic matter was removed. Vegetable charcoal is almost entirely useless for purposes of filtration. It contains an enormous amount of salts soluble in water, renders the latter harder than before passage, and does not purify it as does animal charcoal.

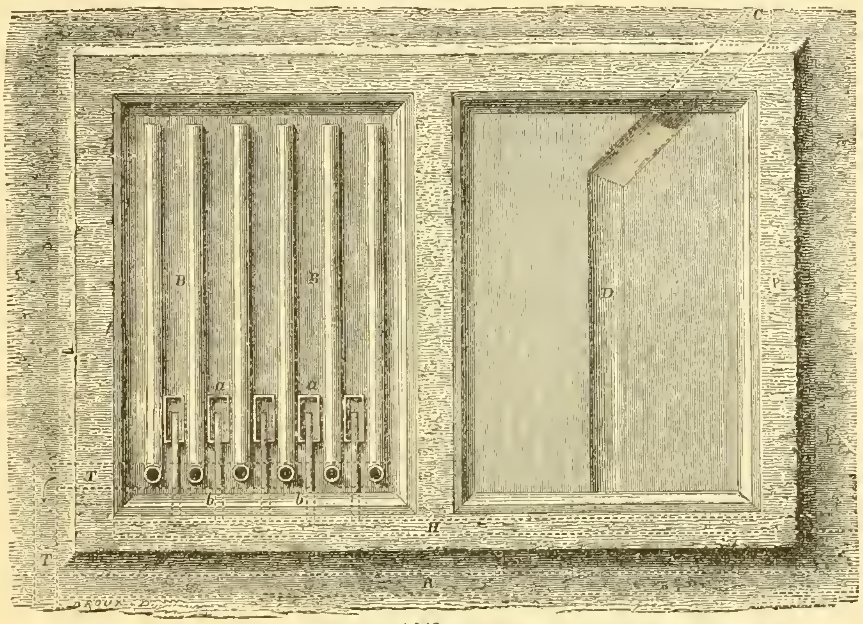
At the Gorbals Filtering Works, near Glasgow, the filtering materials are placed in vertical compartments with passages between them, in each of which the water rises to nearly its original level, and then flows over into the next compartment and down through the filtering material in it. In St.

Petersburg, Russia, the water is made to fall down a series of steps, and then through wire gauze, and lastly through sand filters; and by these means the water, which is generally very impure, is rendered tolerably pure, and a considerable amount of putrescible organic matters is collected from this wire gauze.*

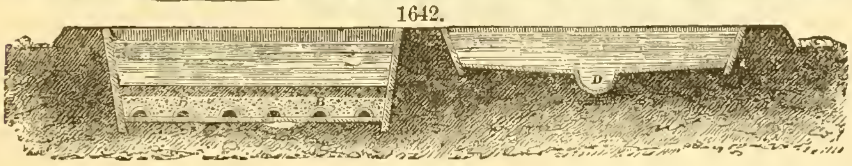
The water both of rivers and of gathering grounds in most cases requires to be filtered. A filter-bed for that purpose, suggested by Prof. Rankine,† consists of a tank about 5 feet deep, having a paved bottom, covered with open-jointed tubular drains leading to a central culvert; the drains are covered with a layer of gravel about 3 feet deep, and that with a layer of sand 2 or 3 feet deep. The water is delivered upon the upper surface of the sand very slowly and uniformly; it gradually descends, and is collected by the drains into the central current. The area of the filter should be such that the water to be filtered may not descend vertically with more than a certain speed; for the whole efficiency of the filtering process depends on its slowness. The speed of vertical descent recommended by some authorities is 6 inches per hour; but according to Rankine, in some cases a speed as high as 1 foot an hour has been used.

From experiments by M. Havrez (*Revue Universelle des Mines*, May, June, 1874, and "Proceedings of the Institution of Civil Engineers," vol. xxxix.), it appears that filtration is influenced by the pressure and temperature of the water, the thickness of the filtering medium, the size of the grains forming the filter, and their mixture. The delivery of a filter per square foot per 24 hours is equal to

1641.



1642.



2.4 cubic yards, multiplied by the pressure of the water in yards and divided by the thickness of the filtering medium in yards nearly. When large and small grains of sand are mixed, the delivery is found to diminish, as also by silting and fouling. Formulæ for the velocity, influenced as stated above, are given in the original paper, to which reference may be made. The filter-beds at Stoke Newington, London, Liverpool, and Dublin are respectively 45,000, 30,000, and 22,500 square feet each in area. Their forms are rectangular, 300 × 150 feet, 300 × 100 feet, and 205 × 110 feet. At London there are 7 beds, with a delivery of 12,000,000 imperial gallons daily; at Liverpool there are 6 beds, with a daily delivery of from 9,000,000 to 12,000,000 gallons; and at Dublin there are 7 beds, with a delivery of 12,000,000 gallons.

Figs. 1641 and 1642 are a plan and section of the classification reservoir and filter basin at Battersea, near London. The reservoir $A$ communicates with the river Thames by a canal $R$, and at the bottom is a semicircular trench $C\ D$, in which sediment from the water is collected. From this basin the water passes through a stone conduit about 1 foot 8 inches in diameter to the filtering basin $E$. At the bottom of this are 6 tubes $B$, separated by intervals of about 5 feet, and pierced with holes to allow of the escape of the water. Above these is placed the filtering bed, composed of 11.7 inches of gravel, 8.7 inches of coarse sand, and 5.8 inches of fine sand. After traversing this filtering layer the water enters the tubes $a\ b$ and escapes at $H$.

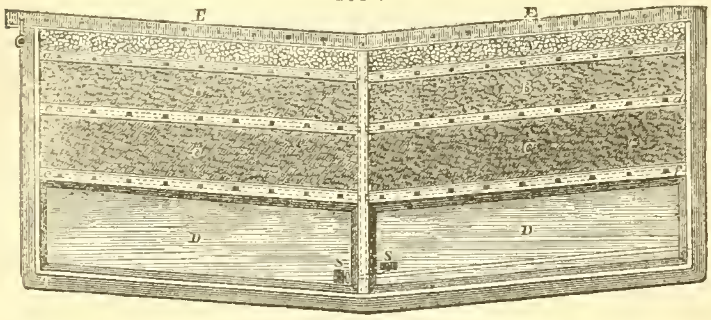
The filtering of the water of Glasgow, Scotland, is conducted on the gravitation system. The water begins by traversing the coarsest material, and proceeds gradually to the finest. The layers, instead of being parallel, are disposed in form of steps of unequal heights. This arrangement will be understood from Fig. 1643. $E$ consists of coarse sand; $B$ is a mass of fine pebbles; $C$ is a

* Abstract of lectures on water supplies, delivered before the School of Military Engineering, 1875, by W. A. Corfield, M. A., M. D.

† "A Manual of Civil Engineering," 11th ed., London, 1876.

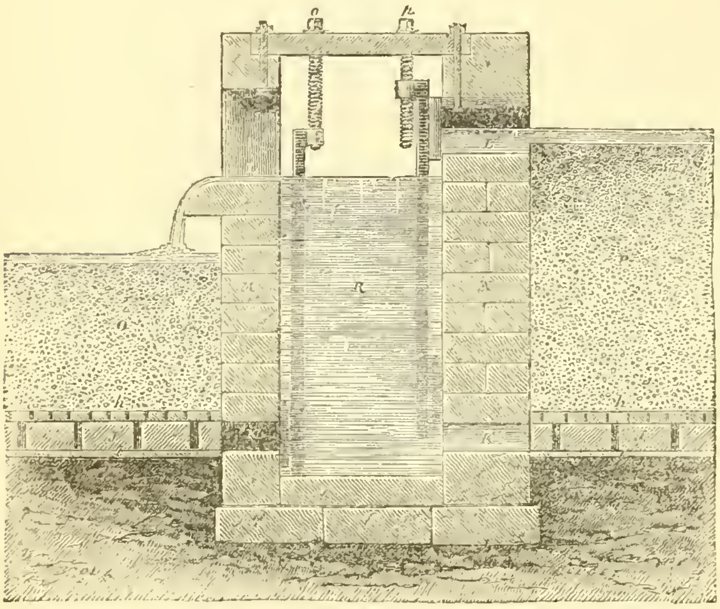
thicker bed of fine sand; and $D D$ is the reservoir. From this the water passes to a conduit, the gates of which are at $S$. In proceeding from one bed to another, the water traverses automatic locks, a section of one of which is given in Fig. 1644, their positions being indicated at $a\ b$, $c\ d$, $e\ f$ in Fig. 1643. $M$ and $N$ are the walls forming the reservoir $R$. $P$ is the upper filter of coarse sand. The water from this passes to a false bottom $h\ l$, formed of bricks $J$ separated and placed on their edges. In the intervening space the water is collected and goes to the channel $K$ in the reservoir $R$, where it rises until it reaches the opening $L$, whence it passes to the filter next in succession. By changing the position of the valves so as to close $K'$ and $L$, and to open $K$ and $L'$, the water from the filter $P$ and reservoir $R$ may be led to a discharge-pipe whenever it is necessary to clean the filters.

1643.

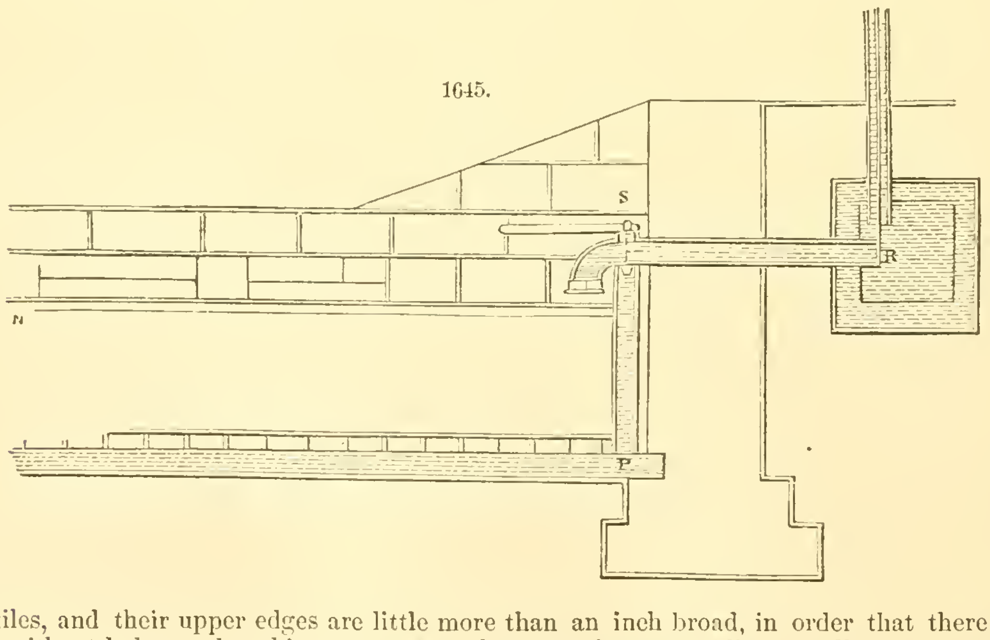


In the filters illustrated in Figs. 1645, 1646, and 1647, the stone pipe $A$ brings the water from the regulating basin to the filters, and iron pipes communicate between the stone pipe or aqueduct and the top and bottom of the filters. A valve near the top of the iron pipe $S\ P$, at $S$, Fig. 1645, forces the water to enter on the top or at the bottom of the filter at pleasure. The filter is 100 feet in length and 60 feet in breadth, divided into three compartments, which may either act together or separately, so that when one compartment is being cleansed, the other two continue in operation. The site of the filters is a piece of level ground, excavated to the depth of 6 or 8 feet, with retaining walls all round, joined with cement, and puddled behind, so as to become water-tight. The bottom is laid about a foot deep with a strong stiff puddle, over which is a pavement so cemented as to be impervious to water. The whole of this bottom is then divided into drains or spaces, 1 foot wide and 5 inches deep, by means of fire-brick laid on edge, and covered with flat tiles of the same material, perforated with small holes, like those used in a kiln for drying oats. These holes are placed very near each other, and are rather more than one-tenth of an inch in diameter; there is also a space of a quarter of an inch left open between the ends of the bricks which support the per-

1644.



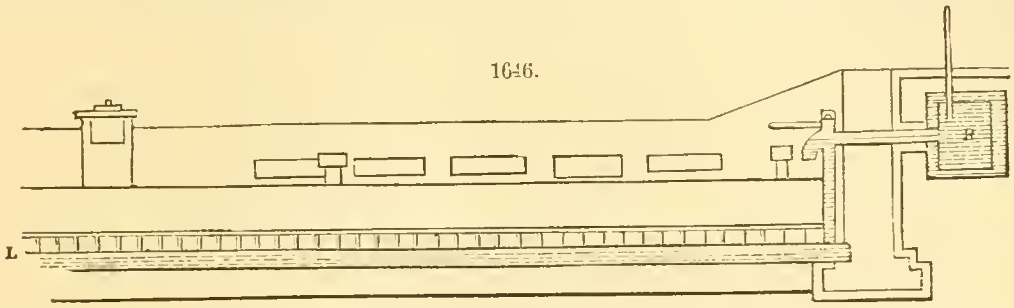
1645.




forated tiles, and their upper edges are little more than an inch broad, in order that there may be no space without holes, and nothing to prevent the water from spreading equally over every part of the bottom of these drains. This is particularly necessary when the filters are being cleaned by the

upward motion of the water. The perforated tiles or plates are covered to the depth of 1 inch with clean gravel, about three-tenths of an inch in diameter; this is followed by 5 other layers of gravel, each of the same depth, and each succeeding layer a little finer than the previous one, the last being coarse sand; over this is placed 2 feet depth of clean, sharp, fine sand, similar to that used in hour-glasses, but a very little coarser; about 6 or 8 inches deep of the fine sand nearest the top is mixed with animal charcoal, ground to the size of coarse meal, each particle about one-sixteenth of an inch in diameter. A longitudinal drain or pipe *N* runs between the filter and the pure-water basin, communicating with both; on each of the openings between the pipe and the filter is a stop-cock to close the communication when necessary; there are also two drains, one to carry off the foul water when the filters are being cleaned, and another to prevent the water from rising too high. When the filter is

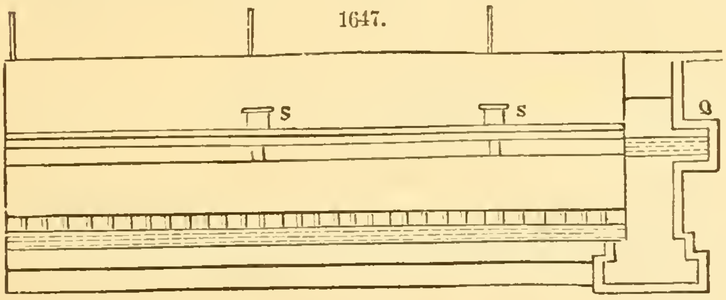
1646.



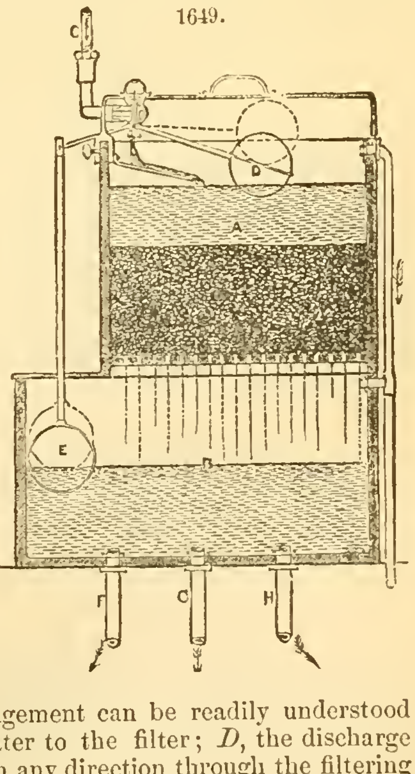

complete, its action is as follows: The sluice *R* and the valve *S* are opened, and the water permitted to flow through the filter into the drain *N* below, until it becomes quite clear. This will take two or three days when first set to work, unless very great pains are taken to wash the gravel and sand before they are put into the filter, which will now flow copiously for some weeks; and when the quantity passing begins to decrease, the stop-cocks are shut and the valves *S S* raised. The water then enters below, filling all the drains, and, having a head pressure of several feet, it will force its way up through the sand to the top, and in its passage raise the scales or particles of mud which have been deposited in the downward passage, and carry them into the foul-water drain below. If the sand of the surface be stirred by a fine-toothed rake after the water has been raised above it, and a little additional water admitted on the top through the conduit, it will facilitate the operation of cleaning, as the mud is always deposited on the very surface of the sand. By this means the sediment will be carried off, and the water pass through quite clear again in a few hours; the valve *S* should then be lowered, the stop-cocks opened, and the operation of filtering will again proceed as above described. The cost of this filter would be about $3,000, and the quantity of pure water produced regularly every 24 hours on an average about 106,632 cubic feet.

M. Fonvielle of Paris has invented a filter in which two currents of water instead of one are

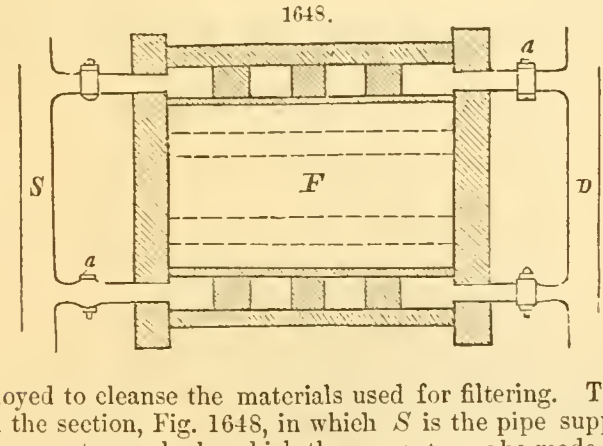
1647.




1649.




1648.




employed to cleanse the materials used for filtering. This arrangement can be readily understood from the section, Fig. 1648, in which *S* is the pipe supplying water to the filter; *D*, the discharge pipe; *a a*, stop-cocks by which the current may be made to pass in any direction through the filtering material *F*, which is supported between two perforated diaphragm plates. When in operation one cock only in each pipe is opened, diagonally opposite, as shown in the section. But to cleanse the filtering materials, both supply-cocks are opened and one discharge-cock, alternately the lower and upper; by this means the filtering materials are effectually cleansed. Filters on this principle, with numerous compartments and of various capacities, are used for the filtration of the waters of the Seine, and give complete satisfaction.

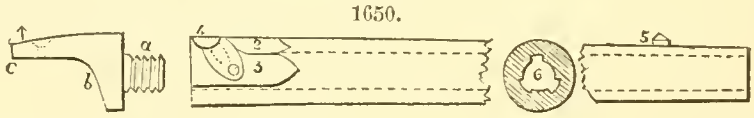
Fig. 1649 represents an improved intermittent filter, the principal feature of which is that it intermittently runs dry, so that the filtering material becomes aërated, and the impurities detached by it from the water are to a certain extent oxidized. During the day, when the water is being drawn off for use, the extent to which aëration and oxidation will take place will, of course, depend upon the rate at which the water is used; but at night several hours may generally be counted upon during which aëration and preparation for further effective filtration may take place. Referring to the section, *A* is the cistern containing the filtering material. The bottom of this is perforated, and is placed over a second cistern *B*, which contains the filtered supply. *C* is the supply-pipe from the main or from a service cistern; and *D* is a ball-cock which regulates the admission of water to the filter as the filtered water is drawn from cistern *B*. The ball *D*, however, cannot fall to admit fresh water except in unison with the ball *E*, which acts by a lever upon the same valve. An interval is thus gained between the admission of water to the filter *A* and the partial emptying of the cistern *B*, and during this interval aëration of the filtering material may take place. *I* is an overflow pipe connected with both cisterns. With reference to this it may be remarked that, although the current induced by the water falling from the cistern *A* will most probably tend to draw air with it as it passes the connection with the cistern *B*, still it is possible, as the short piece of pipe is now placed, for some water from *A* to run unfiltered into *B*. If this piece of pipe were placed at an angle, so as to dip from the cistern, or if the connection were made by a double angle-piece, this risk would be avoided. The pipes *F G H* for supply to different parts of a building may, of course, be placed either at the side or at the bottom of the cistern, and may be more or less in number.

An ingenious centrifugal filter has been devised by MM. Autier and Allaire, the efficiency of which does not depend on the use of any filtering matter, but on the application of a simple mechanical action. Its construction is based on the principle that if a cylinder be set revolving rapidly in a fluid in which solid particles are suspended, the fluid participates in the velocity given to the cylinder, that next it revolving at the highest speed, and the remainder of the fluid at ratios the inverse of their distances from the cylinder. The solid particles suspended in the fluid are thus driven away from the neighborhood of the cylinder, where the fluid is left clear, in which condition it can be led away by properly placed draw-off pipes.

*Works for Reference.*—"Lectures on Water Supplies," Corfield, delivered before the School of Military Engineering, 1875; "A Manual of Civil Engineering," Rankine, 11th ed., London, 1875; "Merveilles de l'Industrie," Figuier, Paris, no date; also works on water-works quoted under CANALS. See also SUGAR MACHINERY.

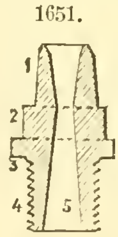
FIRE-ARMS, CONSTRUCTION AND TRIALS OF. The essential parts of all portable fire-arms are the barrel, the lock, the stock, the sights, and the mountings. The principal parts of the barrel, Fig. 1650, are the *breech*, the *breech-screw*, near to the *flats* (3), *bevels* (2), and *oval*; the *cone* and *cone-seat* (4); the *bayonet stud* and *front sights* (5); the *bore*, the *grooves*, and the *lands* (6). The *breech-screw* is composed of the *body* (*a*), *tenon* (*b*), and *tang* (*c*). The object of the breech-screw is to close the bottom of the bore; the tenon fits into a mortise cut in the stock, and prevents the barrel from turning on its bed; the tang is the part by which the breech of the barrel is secured to

1650.

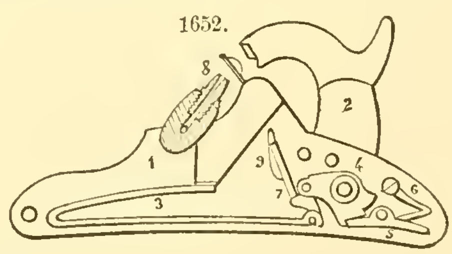


the stock, and for this purpose it is pierced with a hole for the *tang-screw*, which passes through the stock and enters the guard-plate. The *flats* are two vertical plane surfaces, situated at equal distances from the axis of the bore. They serve to prevent the barrel from turning in the jaws of the vise when the barrel-screw is taken out; the flat on the right side of the barrel also presents a surface of contact for the lock-plate, which prevents the hammer and cone from changing their relative positions. The functions of the *cone*, Fig. 1651, are to support the cap when exploded, and to conduct the flame to the vent of the piece. The parts are the *nipple* (1), upon which the cap is placed; the *square* (2), to which the wrench is applied; the *shoulder* (3), the *screw-thread* (4), and the *vent*

1651.



1652.



(5). The *cone-seat* is a projecting piece of iron welded to the barrel near the breech for the purpose of sustaining the cone. The principal parts are the *female screw*, the *vent*, and the *rim;* the last prevents the flame from penetrating between the lock and the barrel.

The ordinary percussion-lock, Fig. 1652, is composed of the *lock-plate* (1), to which the several parts are attached, and by which the lock is fastened to the stock; the *hammer* (2), which strikes upon the cap; the *mainspring* (3), which sets the hammer in motion; the *tumbler* (4), or axle, by which the movement of the spring is communicated to the hammer; the *sear* (5), or lever, the point of which fits into the notches of the tumbler and holds the hammer in the required position: the notches are designated as the *full-cock notch* and *safety notch;* the *sear-spring* (6), which presses the point of the sear into the tumbler notch; the *bridle* (omitted in the figure), which is pierced with two

holes for the inner pivots of the sear and tumbler; the *swivel* (7), which joins the mainspring and tumbler. The more important parts of the stock are the butt, the handle, the beds for the barrel-lock, band-spring, guard-plate, and butt-plate; the shoulders for the tip and bands, and the ramrod groove. The mountings comprise the butt-plate, guard-plate, bands, springs, and tip.

Great improvements have been made everywhere in recent years in military small arms, whereby great efficiency has been gained by diminished weight of piece and cost of manufacture. The following may be enumerated as the principal changes on which these improvements are based, viz.:* 1. The adoption of the rifle-grooves and the elongation of the bullet. 2. The loading at the breech, and the metallic-case cartridge, by which the joint is closed against the escape of the flame of the charge. 3. The reduction in the diameter of the bore and the length of the barrel. 4. The substitution of low steel in place of wrought-iron in the manufacture of the principal parts, and especially the barrel, and the American plan of manufacture by machinery, making all parts interchangeable for repairs. The reduction in length of the barrel has been from 8 to 10 inches; the reduction in the diameter of bore and the weight of ammunition is shown in the following table:

| COUNTRIES. | CALIBRE. | | POWDER. | | PROJECTILE. | |
|---|---|---|---|---|---|---|
| | Old Muzzle-loading. | New Breech-loading. | Old. | New. | Old. | New. |
| | Inch. | Inch. | Grains. | Grains. | Grains. | Grains. |
| England | .577 | .45 | 62 | 85 | 504 | 480 |
| France | .69 and .72 | .43 | 77 | 85 | 494 | 380 |
| Prussia | .62 | .45 | 86 | 80 | 360 | 380 |
| Austria | .55 | .425 | 62 | 68 | 450 | 318 |
| Russia | .60 | .42 | 80 | 80 | 560 | 375 |
| Bavaria | .... | .45 | 66 | 66 | 675 | 340 |

*Breech-loading Fire-Arms.*—From a valuable digest of "Patents relating to Breech-loading and Magazine Small Arms," by V. D. Stockbridge, Examiner U. S. Patent Office (Washington, 1874), we take the following classification:

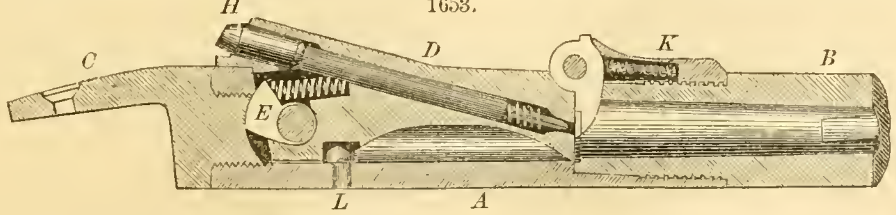
**Class A.** *Movement of Barrel.*
- 1. Sliding longitudinally forward.
- 2. Tilting
  - (*a*) Up at breech.
  - (*b*) With muzzle upward.
- 3. Hinged or jointed to stock.
- 4. Swinging laterally on vertical pin.
- 5. Rotating on parallel longitudinal pin.

**Class B.** *Movement of Breech-block.*
- 1. Sliding longitudinally backward
  - (*a*) Operated by lever.
  - (*b*) Operated by handle.
- 2. Swinging or tilting
  - (*a*) Upward and forward.
  - (*b*) Laterally forward.
  - (*c*) Backward and downward.
  - (*d*) On centres and trunnions.
  - (*e*) Upward and backward.
  - (*f*) Laterally backward.
  - (*g*) Downward and backward.
  - (*h*) On a longitudinal pin or hinge.
- 3. Sliding transversely through mortise.
  - (*a*) Moving vertically.
  - (*b*) Moving laterally.
- 4. Faucet or spigot
  - (*a*) Chamber in faucet.
  - (*b*) Chamber in front of faucet.
- 5. Rotating sleeve, etc.

**Class C.** *Revolvers.*
- 1. Chambered cylinder revolving on parallel axis
  - (*a*) Behind a barrel; cylinder charged in front.
  - (*b*) Behind a barrel; cylinder charged in rear.
  - (*c*) Cylinder without other barrel: pepper-box.
- 2. Chambered cylinder revolving on vertical axis behind a barrel.
- 3. Chambered cylinder revolving on horizontal transverse axis behind a barrel.
- 4. Revolving hammer acting on several stationary barrels.

These weapons may also be divided into the two principal classes of single-loaders and magazine or repeating guns.

1653.

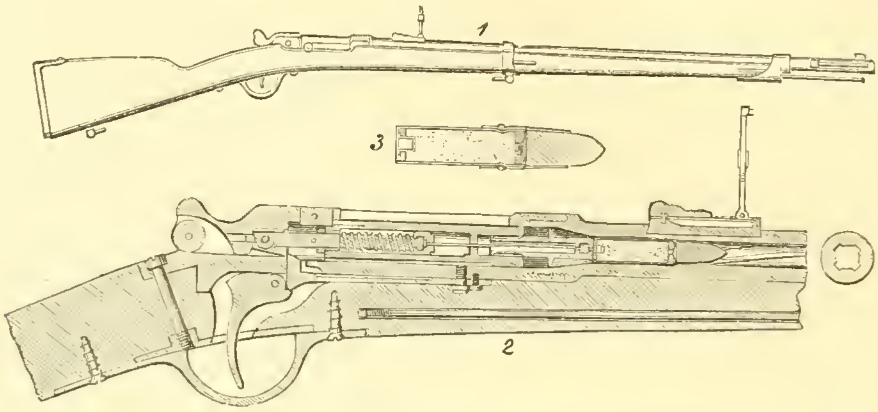



*Single-loaders.*—Fig. 1653 represents the breech mechanism of the Springfield rifle, the manufacture of which is described in detail in the succeeding article. *A* is the receiver; *B*, the barrel with

* From Report of Chief of Ordnance, U. S. A., 1877.

its screw-thread; *C*, the breech-screw with circular recess to receive the cam-latch *F; D*, the breech-block, turning around the hinge-pin shown on the right; *H*, the firing-pin, which transmits the blow of the hammer to the priming of the cartridge. Beneath this pin is shown the cam-latch spring which presses the latch *F* into the recess in *C*. *J* is the extractor to withdraw the empty cartridge-shell after firing, and *K* is the ejector-spring and spindle. When the breech-block is closed, the point of the ejector-spring spindle presses against the extractor above the position of the axis of the hinge-block, and no motion takes place. When the breech-block is raised so as to press against the lug shown on the upper portion of the extractor *J*, the point on the lower part of the latter moves slowly to the rear, withdrawing the shell—the upper part of the extractor meanwhile compressing the ejector-spring. When the direction of the pressure of the spring passes below the centre of the hinge, the extractor moves rapidly and throws the shell clear of the receiver. *L* is the ejector-stud, which serves to deflect the shell upward and thereby clear the well of the receiver. The firing-pin spring, shown at the lower end of the pin and used to press the latter back when the hammer is

1654.



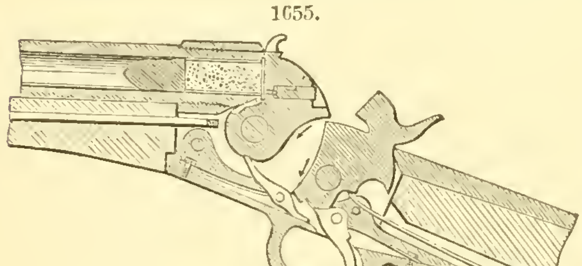

1. Gun complete. 2. Section showing lock and rifling of gun ready to fire. 3. Cartridge.

raised, has been abolished. The arrangement of the cam and eccentric handle for lifting the block is such that, unless the block is closed, the hammer cannot strike the firing-pin, but will merely strike the handle. The calibre is .45 inch; the barrel has three grooves equal in width to the lands, and the rifling has a twist of 22 inches. The length of the barrel is 36 inches (with receiver), and of the stock 48.7 inches. The piece weighs 8.68 lbs. without the bayonet. The weight of the powder charge is 70 grains and of the ball 405 grains.

*The French Chassepot Rifle*, Fig. 1654.—In this weapon there is a bolt-handle by which the bolt is held in place, the latter containing lock and needle. The fulminate is in a paper wad, which forms the rear of the cartridge envelope. The gas-check is a cylindrical ring of vulcanized India-rubber, which is pressed against the surface of the chamber when the explosion takes place. The number of grooves is four. An opening on the right hand of the chamber allows of the insertion of the cartridge, which by the forward thrust of the knob is driven into the breech, when a partial rotation of the knob locks the breech-piece.

*The Remington Rifle*, Fig. 1655, is a single breech-loader, using metallic cartridges. An iron receiver, made to correspond externally to the shape of a gun-stock, is screwed to the breech of the barrel; in this are contained the breech-block and lock. Supposing the piece to have been discharged, it is loaded as follows: 1, it is cocked; 2, the breech-block is pulled back by the handle at its right side, ejecting the shell of the exploded cartridge; 3, the cartridge is inserted; 4, the breech-block is pushed back to its place, closing the breech. The gun is then ready for firing. The hammer has a projection which passes under the breech-block when it is down or closing the breech, and prevents the block from flying back when the explosion takes place. The firing-pin passes the breech-block from the nose of the hammer to the percussion-cap in the base of the cartridge-shell.

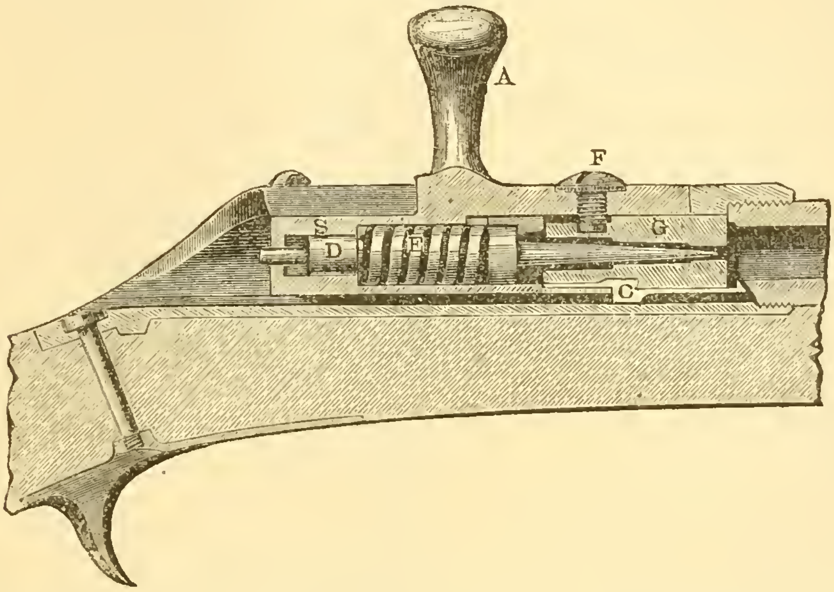
1655.



*The Pieri Rifle*, Fig. 1656.—The principle of this arm is the same as that of the Dreyse, Chassepot, Berdan, and Vetterlin guns. The breech mechanism consists in all of only seven pieces: the cylinder, with handle, *A* and *S*; the trigger-spring, *H*; the head-piece, *G*; the extractor, *C*; the spiral spring, *E*; the thumb-screw, *F*; and the striker, *D*. The cylinder is bored throughout its whole length, to receive within it the spiral spring, the striker, and the head-piece. The striker is larger in diameter at one end than at the other. Between the two portions is a raised part, against which the end of the spiral spring bears, and this raised part carries a tooth or projection, the extremity of which has a spiral surface. The other end of the striker has a notch in it for the tooth of the trigger-spring to work in. The head-piece is bored throughout, in order to give a passage for the point of the striker, and has the form of two connected cylinders of different diameters. The surface of the cylinder of greater diameter has a groove parallel to the axis in which the extractor *G* is placed, and in the cylinder of lesser diameter is a groove in which the point of the thumb-screw works. On the rear face of this last piece is a small notch, in which the point of the projection on

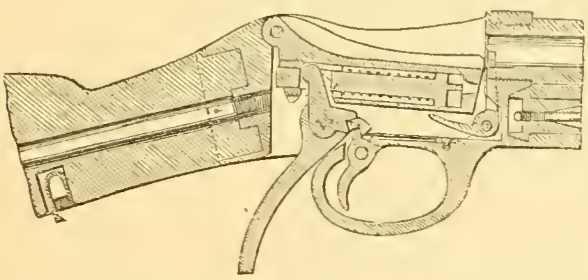
the striker lodges when the arm is at full cock. The trigger-spring, which is placed in a groove in the cylinder, is provided with two teeth, one to prevent the spring from withdrawing from the cylinder, the other to take the notch in the striker. The spring projects to the rear of the cylinder and terminates in a thumb-piece, which is pressed when wishing to fire. The thumb-piece is protected by the two wings of the breech-shoe from injury or accidental blows. To load the rifle, the handle of the cylinder is turned up and drawn back until the head of the thumb-screw lodges against the

1656.

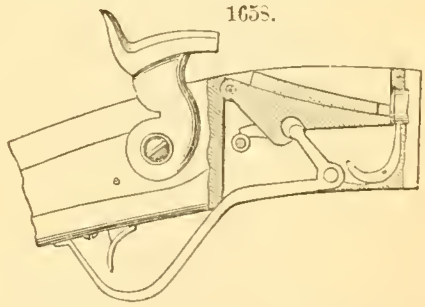



head formed on the breech-shoe. The rotation of the cylinder is not given to the head-piece, which is prevented from rotating by the projection on the extractor, which works in a groove cut along the bottom of the breech-shoe. By virtue of this the projection on the striker is compelled to rotate with the cylinder over the spiral surface of the cavity in the head-piece, and consequently to go back in the cylinder until the projection in the trigger-spring enters the notch in the striker, when the spring is compressed. The cartridge having been placed in the chamber, the cylinder is forced for-

1657.



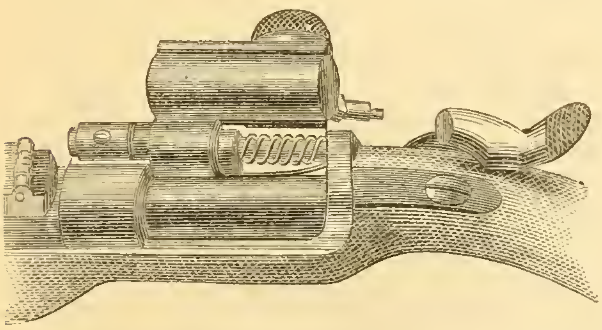
1658.



ward and turned to the right, by which movement the projection on the striker is brought opposite the cavity in the head-piece, and the arm is ready to be discharged.

*The Martini-Henry Rifle*, Fig. 1657.—The breech-block is pivoted at its upper rear portion, being moved up and down by a lever at the rear of the trigger-guard. The firing is by a spiral spring which actuates a firing-pin. The cartridge-shell extractor works on a pivot below and behind, the barrel being operated by the descent of the front end of the breech-block upon one arm of the bell-crank lever.

1659.



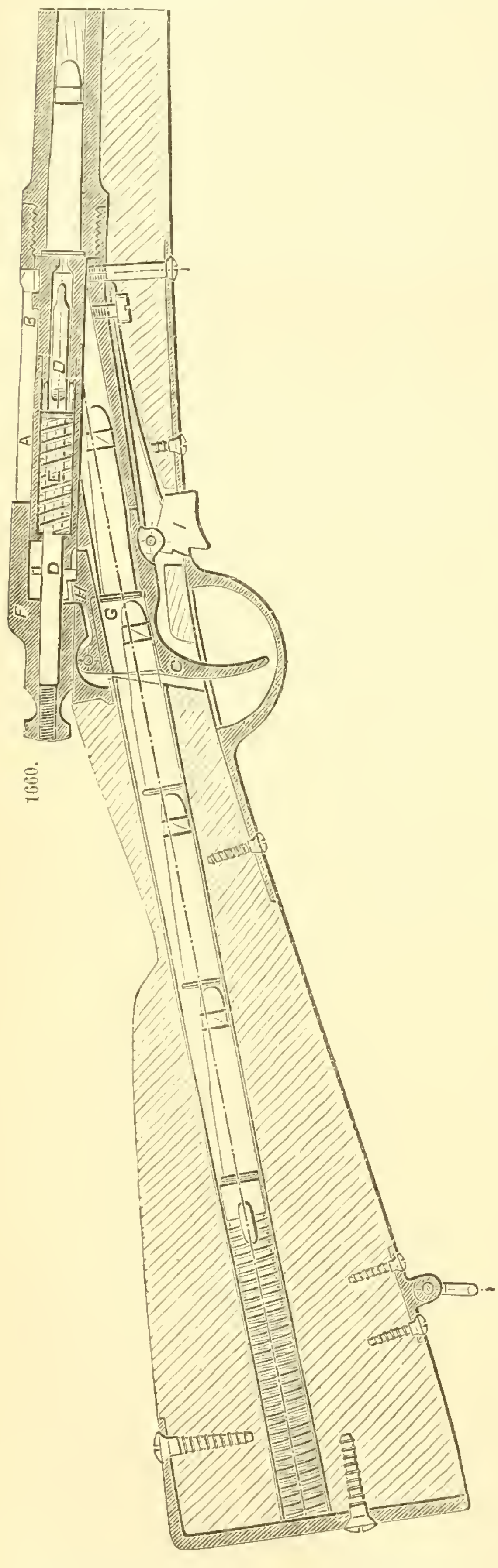
*The Peabody Rifle*, Fig. 1658.—There is a falling breech-block hinged at the rear and depressed by the guard-lever, whose short arm engages in a recess of the block and controls its movements. When the block is down, the cartridge is slipped into the bore, and the piece is fired by the fall of the hammer upon a firing-pin sliding in a groove in the side of the block. In opening to reload, the block drops upon an elbow lever, and withdraws the spent cartridge-shell.

*The Snider Rifle*, Fig. 1659.—The breech-block is hinged to the rear and above the barrel, the block throwing upward and forward, and exposing a chamber in rear of the bore. Into this the cartridge is dropped, pushed into the bore, the block brought down and locked by a latch in the rear. The firing-pin passes obliquely through the block, and is struck by the ordinary hammer.

Carbines in the U. S. army differ from the Springfield rifles only in the length of barrel and stock, and in various minor fittings which need no special reference. The total length of the barrel

is 25.4 inches, and that of the stock 29.85 inches. The total weight of the arm is 7.17 lbs., of the charge 55 grains, and of the ball 405 grains.

The most complete series of tests yet made on breech-loading arms was conducted in 1872–'73 by a U. S. Army Board, the report of which will be found in "Ordnance Memoranda," No. 15, Washington, 1873. Ninety-nine models of American arms were tested, together with the Chassepot needle-gun, needle-carbine, Mauser, Werndl, Werder, Vetterlin, and Martini-Henry systems, as representative of the best foreign practice. The nature of the trials was substantially similar to that of the trials of magazine guns in 1878. On the conclusion of the first series of tests the following guns were ordered to supplementary trial: Peabody, No. 63; Whitney carbine, No. 77; Springfield-Stillman, No. 66; Elliot carbine, No. 80; Ward-Burton magazine carbine, No. 58; Updegraff, No. 42; Sharps, No. 5; Springfield, No. 69; Remington-Ryder, No. 67; Berdan Russian, No. 57; Freeman, No. 76; Dexter, No. 38; Lee, No. 61; Roberts, No. 2; Remington locking rifle, No. 82; Winchester, No. 78; Broughton, No. 79; Sharps, No. 81; Remington navy rifle, No. 85; and of the foreign arms, the Martini-Henry and Werndl. Out of the 21 arms thus selected, after undergoing supplementary testing, six were chosen to be altered to calibre, .45 inch, that calibre having been determined upon by a board of U. S. army officers (see also "Ordnance Memoranda," No. 15) as the most advantageous one for small arms. The six were the Springfield, Elliot, Ward-Burton, Remington, Freeman, and Peabody. These were thoroughly tested, and the result was the victory of the Springfield system and its subsequent adoption into the military use of the United States. The Board strongly advocated magazine guns, and pointed out that "whenever an arm shall be devised which shall be as effective as a single breech-loader, as the best of the existing single breech-loading arms, and at the same time shall possess a safe and easily manipulated magazine, every consideration of public policy will require its adoption." In this connection, see final tests of the Hotchkiss gun, trial of 1878.



1660.

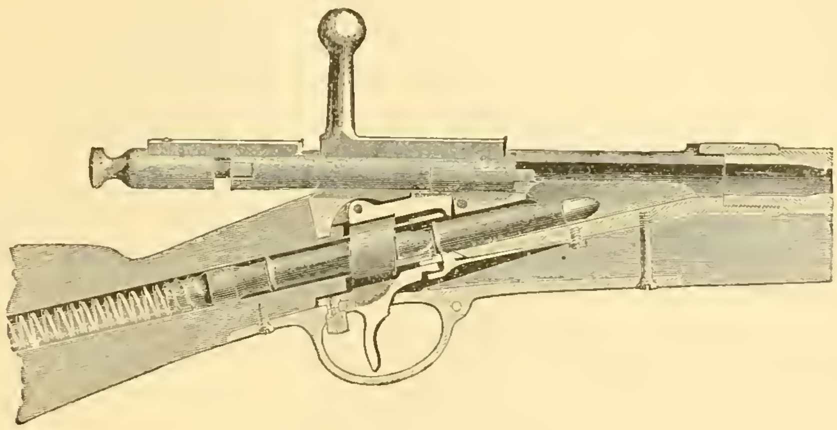
Magazine or Repeating Rifles.—An exceedingly valuable and complete series of tests of the principal types of weapons of this class was conducted at the National Armory, Springfield, Mass., in April, 1878. The details of the experiments and other data are given in the report of the Chief of Ordnance, U. S. A., 1878. An abstract of the results of this trial will be found further on.

*The Hotchkiss Magazine Gun.*—This weapon belongs to that class which has a fixed chamber closed by a movable breech-block which slides in the line of the barrel by direct action; i. e., bolt-guns which have concealed locks. It is the device of Mr. B. B. Hotchkiss, the inventor of the revolving cannon described under Ordnance. In exterior appearance this arm resembles an ordinary single-shot bolt-gun. The magazine is in the butt end of the stock; the supply of cartridges from the magazine can be cut off by moving a thumb-piece placed on the left side of the receiver or "shoe," and the gun is then loaded and fired as a single-loader. The peculiarity of the arm consists in the construction of the magazine movement and in the breech mechanism, or system. This consists of but 6 parts, Fig. 1660, viz.: Breech-bolt, *A;* recoil-block, or nose-piece, *B;* hammer, *C;* firing-pin, *D;* firing-pin spring, *E;* and extractor, *F.* The magazine is located in the stock, and the cartridges are propelled forward by a spiral spring. Their motion is, however, governed as follows: The trigger *C* is traversed by a tubular passage, of sufficient size to allow the cartridge to be fed through it into the magazine and to pass in the opposite direction to the chamber. The axis of this tubular

passage is not quite in the same line with the passage in the receiver. This displacement is so arranged that the body of the cartridge can pass, but not the head. When the trigger is pulled to fire the gun, the trigger-passage and that in the receiver are brought to coincide. A cartridge is thus liberated and allowed to pass through by the pressure of the magazine-spring into the receiver. The action of closing the bolt then pushes the cartridge into the chamber ready to be fired. Hence, each time the trigger is pulled to fire the gun, one cartridge is liberated, and the extraction of the empty shell and closing of the gun is necessary to bring the new cartridge into firing position.

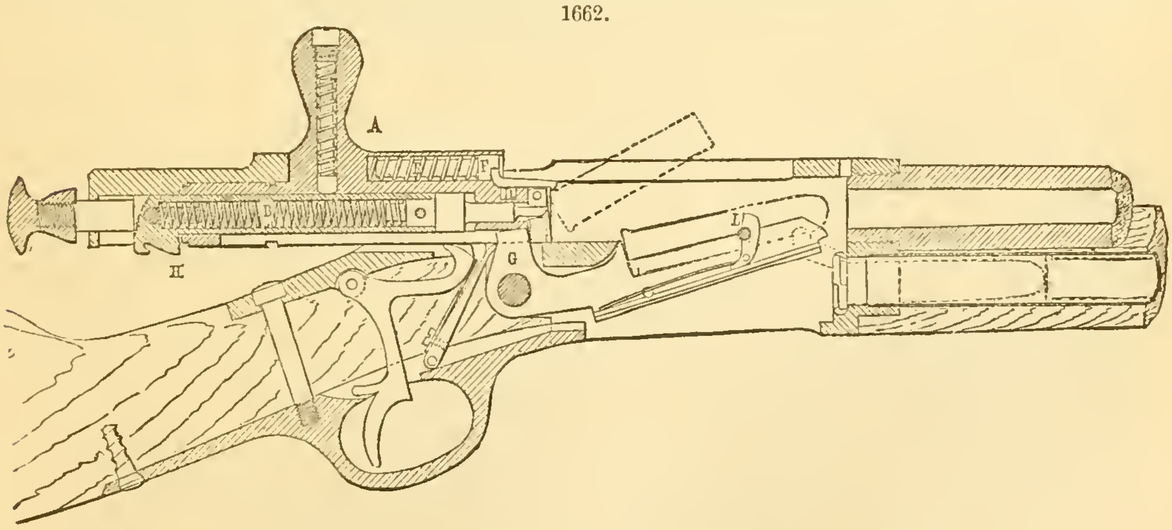
The gun, when used as a repeater, is operated by 3 motions, viz.: Opened, closed, fired. When used as a single-loader, it is operated by 4 motions, viz.: opened, loaded, closed, fired. To open the

1661.



piece, the handle of the breech-bolt is raised, and then withdrawn as far back as possible. This brings back at the same time the nose-piece, and also the firing-pin is retracted. The gun is by this action cocked. The nose-piece, meanwhile, is kept from turning by the resistance afforded by the projection on it against the receiver, which allows the nose-piece to follow only the longitudinal motion of the bolt. By reversing the movement of the bolt, the nose-piece catches against the head of the cartridge and shoves it up the incline of the receiver into the chamber. In pushing forward the bolt, the lower edge of the hammer catches against the sear *H*, and is retained by it during the remaining slight forward motion of the bolt. This motion is imparted to the bolt by its bearing against the beveled surface of the rear shoulder of the mortise in the receiver, while the handle is turning down into place. To fire the gun, the trigger is pulled and the sear is disengaged from its hold against the face of the hammer. This allows the firing-pin spring to impel it forward, and to drive the firing-pin against the percussion-cap in the cartridge. Extraction is provided for by a strong spring-hook extractor, carried by the nose-piece. The natural spring of the extractor presses the rim of the cartridge against the side of the receiver, and by the friction thus created the cartridge is thrown sideways round the hook of the extractor and clear of the gun. The cartridges

1662.




are loaded into the magazine from its forward end, the bolt being previously drawn backward, so as to expose that part of the magazine-passage which connects between the stock and the chamber in the barrel.

Fig. 1661 shows the same gun with various minor improvements, and represents one of the variations of the form which proved victorious in the tests above referred to. For performances of this and other weapons, see table on page 789. In the improved model, five cartridges are carried in the magazine and one in the chamber.

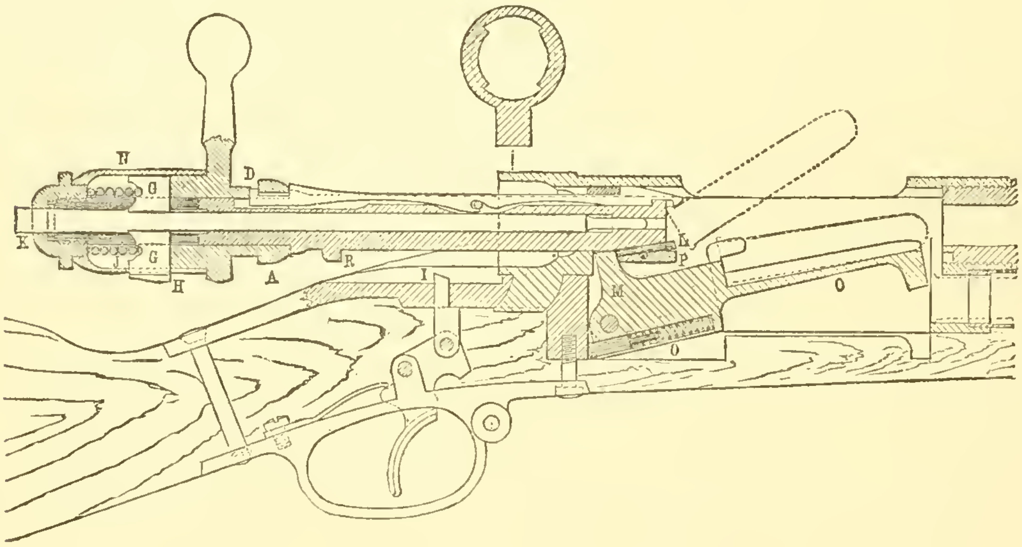
*The Remington Magazine Gun*, Fig. 1662.—This gun belongs to the system in which a fixed chamber is closed by a bolt by direct action, and in which the lock is concealed. The breech-bolt is composed of three parts, viz.: the body or locking-tube *A*, the cocking-piece *B*, and the portion by which these are connected. The extractor lies in front of the rib of the locking-tube, and its tenon enters

a recess in the side of the latter. When the bolt is unlocked, the extractor rides around the head of the cartridge. The ejector is struck by the carrier-lever *G* when the bolt is withdrawn. The extractor then pulls on the upper side of the cartridge, while the under side is struck by the ejector. The effect is to throw the shell clear of the gun. The cocking-piece *B* receives the firing-pin and spring, and a projection *H* upon it enters a recess in rear of the locking-tube. The form of this projection and that of its corresponding recess is such as to cam back the half-cock notch to pass beyond the sear, at the same time withdrawing the point of the firing-pin within the face of the bolt. The piece may be full-cocked by pulling the cocking-piece to the rear by the button with which it is terminated, or by drawing back the bolt and then returning it to its locking position. The magazine is in the tip-stock. The carrier is pivoted on a strong screw through the side of the receiver. Its lever works in a groove in the bottom of the locking-tube. When the bolt is withdrawn, the front end of the groove strikes on the lever and tips the carrier up in a position oblique to the axis of the bore, bringing the point of the cartridge opposite the centre of the chamber. The carrier is held in this position by the catch *L*, which springs over a pin on the inner surface of the receiver. When the bolt is closed, its front presses against the catch and releases it, while the rear end of the groove in the bottom of the locking-tube strikes the carrier-lever and causes the carrier to descend opposite the mouth of the magazine. When the bolt is unlocked, the side of the groove presses down on this end, and the stop moves downward, permitting a cartridge to come out of the magazine on the carrier. The stop is so constructed that a projection on its upper side descends just in front of the rim of the cartridge as the lower part falls in rear of it, so that the escape of a second cartridge is prevented. When the bolt has been withdrawn, the spring returns the stop to its first position. A magazine cut-off is provided, which works in connection with the cartridge-stop.

The magazine is loaded from below, and in any position of the bolt. As a magazine gun, 3 motions are necessary to operate it, viz.: opened, closed, fired. As a single-loader, 4 motions are necessary, viz.: opened, loaded, closed, fired. This gun carries 8 cartridges in the magazine and 1 in the chamber.

*Sharps Rifle Company's Magazine Gun*, Fig. 1663.—This gun belongs to that system in which a fixed chamber is closed by a bolt, by direct action, and in which the lock is concealed. The receiver

1663.

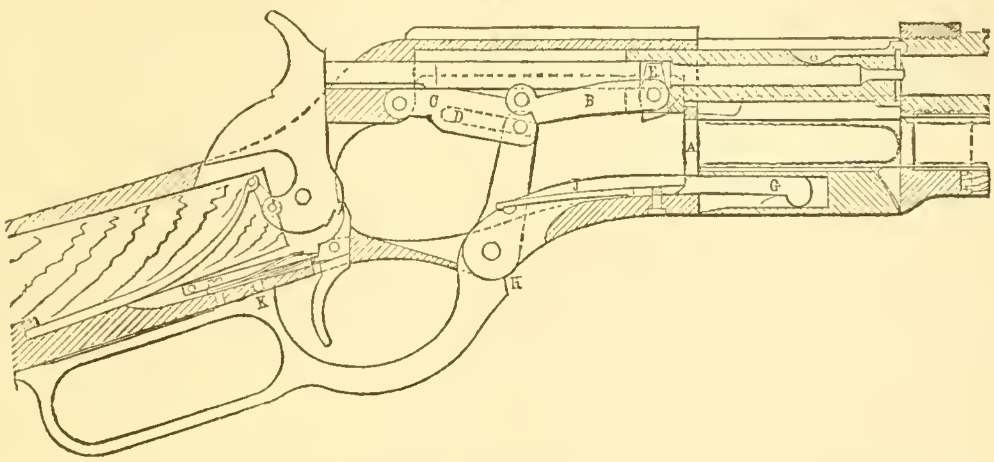



has a slot in its upper surface for the purpose of loading the chamber or filling the magazine. It is bored through at rear for the reception of the breech-bolt, which is composed of two principal parts, the body and the locking-tube. The bolt is locked by lugs *A* on the locking-tube, turning in corresponding cuts in the receiver. The bolt carries on its upper surface the extractor, which is of the ordinary spring-hook pattern, and in its axis the firing-pin, which extends the whole length of the bolt. The spiral form of the face of the locking-tube and of the shoulder of the bolt is such as to cam the bolt up against the head of the cartridge when the bolt is locked. On the rear face of the locking-tube are two spiral surfaces, which bear against corresponding surfaces *G* of the firing-pin. The unlocking of the bolt cams back the firing-pin until the point *H* passes beyond the nose *I* of the sear. When the handle is turned down to lock the bolt, the firing-pin spring is compressed between the shoulders *J* on the pin and the nut *K* on the extreme rear of the bolt. On withdrawing the nose of the sear, the firing-pin, under the influence of its spring, moves forward and explodes the cartridge. The shell is ejected by the ejector-pin *L*, which strikes against the lever *M* of the carrier when the bolt is withdrawn, and is driven forward against the lower side of the head of the shell, while the extractor is pulling on the upper. The magazine is in the tip-stock. The carrier is shown at *O*. When the breech-bolt is withdrawn, the projection *P*, in which the ejector-pin is situated, strikes the lever *M* of the carrier, tipping the latter up in a position oblique to the axis of the bore, bringing the point of the cartridge nearly opposite the centre of the chamber. The carrier is held in this position by the pin and spring shown at *Q*. When the bolt is closed, the cartridge is driven into the chamber, while the projection *R* on the bolt strikes the lever, causing the front of the carrier to descend opposite the mouth of the magazine to receive another cartridge. As a magazine gun, 3 motions are necessary to operate it, viz.: opened, closed, fired. As a single-loader, 4 motions are

necessary, viz.: opened, loaded, closed, fired. This gun carries 9 cartridges in the magazine, 1 in the carrier, and 1 in the chamber.

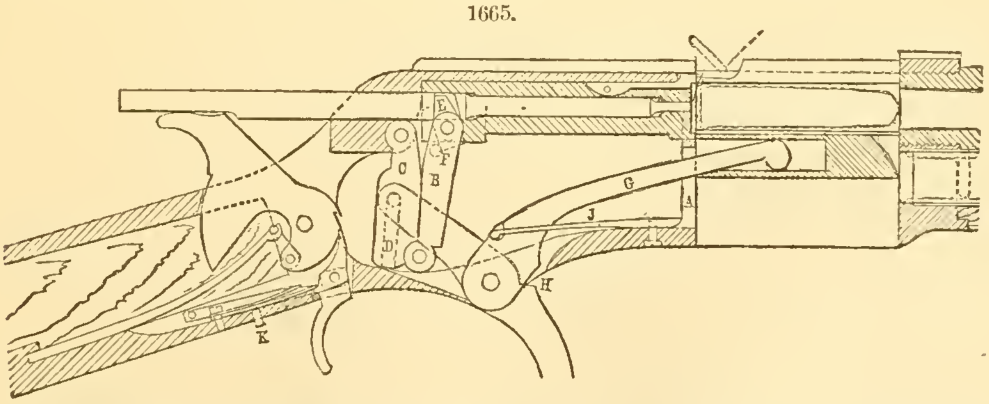
*The Winchester Magazine Gun.*—This gun, manufactured by the Winchester Repeating Arms Company of New Haven, Conn., belongs to that system in which a fixed chamber is closed by a bolt, sliding in line with the axis of the barrel, and operated by a lever from below. The receiver, Figs. 1664 and 1665, is divided by a vertical partition $A$ into two parts. The carrier occupies the front

1664.




portion, while the rear contains, with the exception of the breech-bolt lever, the mechanism necessary to operate both breech-bolt and carrier. The breech-bolt is a single piece, at the upper front end of which is the extractor (of the spring-hook pattern) pinned to it, and at its rear a mass of metal which supports at either side the front end of one of two side links, $B$ and $C$, which form a knuckle-joint. The rear ends of the other links bear against the rear of the receiver, giving the necessary support for the bolt in firing. The outer ends of the links are pivoted to the bolt and receiver. A groove $D$, on the inside of each rear link, receives the end of a strong pin on the breech-bolt lever. Motion of the lever consequently produces a corresponding motion of the links, and through them of the bolt. The firing-pin extends the whole length of the receiver. Its point is retracted within the face of the bolt, when the bolt is drawn back, by a small lever $E$, one end of which enters a recess in the pin, while the other strikes against the pin $F$, Fig. 1665, causing the lever to rotate about the pivot through the front end of the links attached to the breech-bolt. A flat spring (not shown in the figures) bearing against the surface of the breech-bolt lever holds it in place. The hammer is cocked by the end of the firing-pin when the breech-bolt lever is thrown forward. The piece is fired by a centre lock of the usual pattern. A safety device or sear prevents the pulling of the trigger when the piece is unlocked. When the breech-bolt lever is closed, it strikes the pin $K$ projecting from the under side of the sear, and removes it from the safety position. Shells are ejected by the carrier, which, rising as they are being withdrawn, strikes them at a distance of about one-third their length from the rear, and rotates them about the extractor, throwing them clear of the gun. The magazine is in the tip-stock. It is loaded through a gate in the side cover of the receiver, as is also the piece when used as a single-loader. The carrier is moved at right angles to the axis of the barrel by its lever $G$. This lever is thrown up by the shoulder $H$ of the breech-bolt lever striking its under surface when the latter is thrown open. The carrier-lever is depressed in a similar manner when the breech-bolt lever is closed, by the latter bearing on a shoulder on its upper surface. The spring $J$ holds the lever and carrier in either position, Figs. 1664 and 1665. In rising, the carrier does not completely uncover the mouth of the magazine; cartridges cannot therefore escape below

1665.




it. As a magazine gun, 3 motions are necessary to operate it, viz.: opened, closed, fired. As a single-loader, 4 motions are necessary, viz.: opened, loaded, closed, fired. The motions of opening and closing might perhaps be classed as a single motion, being continuous, the hand not being removed from the lever. This gun carries 9 cartridges in the magazine, 1 in the carrier, and 1 in the chamber.

Among other well-known forms of magazine guns are the Hunt, which belongs to the class in

which a fixed chamber is closed by a bolt by direct action, but has a centre lock; the Ward-Burton, belonging to the same general class as the Hotchkiss and Sharps; the Burgess and the Tiesing, in which a fixed chamber is closed by a bolt sliding in line with the axis of the barrel and operated by a lever from below, both guns belonging to the same class as the Winchester. The Chaffee and Buffington guns have fixed chambers closed by movable breech-blocks, sliding and rotating, and operated by a lever from below. The Springfield-Clemmons and Springfield-Miller arms have fixed chambers closed by movable breech-blocks, which rotate about horizontal axes at 90° to the axis of the barrel, lying above the axis of the barrel and in front. Both are adaptations of the Springfield breech-loading rifle previously described. The Lewis-Rice gun belongs to the system in which a fixed chamber is closed by a movable breech-block rotating about a horizontal axis at right angles to and below the axis of the barrel, and in front, and in which the lock is concealed. The Franklin, Burton, and Lee guns belong to the same class as the Hotchkiss and Remington. For detailed descriptions of all these, the reader is referred to the report of the Chief of Ordnance, U. S. A., 1878.

*The Springfield Arsenal Tests of Magazine Guns*, 1878.—The following were the principal conditions of trial (for results, see following table): 1. Safety-test. The piece to be fired 10 rounds by the exhibitor or with a lanyard. 2. Rapidity with accuracy. The number of shots which, fired in two minutes from the gun—both as a magazine gun and as a single-shooter—strike a target 6 feet by 2 feet at a distance of 100 feet. The test to be begun with the chamber or magazine filled; other cartridges to be disposed at will on a table. 3. Rapidity at will. The number of shots which can be fired in one minute, irrespective of aim, under the same circumstances as in test 2. 4. Endurance. Each gun to be fired 500 continuous rounds without cleaning, using the magazine. The state of the breech mechanism to be examined at the end of every 50 rounds. 5. Defective cartridges. Each gun to be fired once with each of the following defective cartridges: 1, cross-filed on head to nearly the thickness of the metal; 2, cut at intervals around the rim; 3, with a longitudinal cut the whole length of the cartridge, from the rim up; a fresh piece of white paper, marked with the number of the gun, being laid over the breech to observe the escape of gas, if any occur. 6. Dust. The piece to be exposed in the box prepared for that purpose to a blast of fine sand-dust for 2 minutes; to be removed, fired 20 rounds, replaced for 2 minutes, removed, and fired 20 rounds more. 7. Rust. The breech mechanism and receiver to be cleansed of grease, and the chamber of the barrel greased and plugged, the butt of the gun to be inserted to the height of the chamber in a solution of sal-ammoniac for 10 minutes, exposed for 2 days to the open air standing in a rack, and then fired 20 rounds. 8. Excessive charges. To be fired once with 85 grains of powder and one ball of 405 grains of lead, once with 90 grains and one ball, and once with 90 grains and two balls. The piece to be closely examined after each discharge.

The following supplementary tests were made upon guns which successfully withstood the foregoing: 1. To be fired with two defective cartridges, Nos. 1 and 2, and then to be dusted 5 minutes, the mechanism being in the mouth of the blow-pipe, and closed, the hammer being at half cock; then to be fired 6 shots, the last two defective Nos. 1 and 2; then without cleaning to be dusted with the breech open, and fired 4 shots. The piece to be freed from dust only by pounding or wiping with the bare hand. 2. To be rusted for 4 days after immersion as before, and then fired 5 rounds with the service cartridge; then without cleaning to be fired 5 rounds with 120 grains powder and a ball weighing 1,200 grains; the gun to stand 24 hours after firing without cleaning, and then to be thoroughly examined. 3. Facility of manipulation by members of the Board. 4. Liability to accidental explosions of cartridges in the magazine. Additional tests may be made by the Board to clear up doubts raised by previous trials.

Sporting Arms.—*Smooth-Bores.*—The bores of shot-guns are made in four ways: 1st, cylindrical; 2d, drawn; 3d, choked; and 4th, bell-muzzled. The cylindrical bore is of uniform size throughout. The drawn bore is less in diameter at the muzzle than at the breech, the decrease however being very small. Choked-bore guns have near the muzzle a slight swelling or ridge, the bore being cylindrical; and in bell-muzzled guns the bore is enlarged or slightly flared at the muzzle. The object of drawing and choking is to bring the shot together, and give a more advantageous "pattern." This term is used to designate the number of pellets projected into a circular target 40 inches in diameter at about 30 yards range. Bell-muzzling increases the dispersion of the shot. In choke-bore guns, it is supposed that the shot in passing out impinge upon the choke or ridge, and are deflected inward toward the axis of the bore. Most sportsmen favor a moderate choke, as it is claimed to afford even pattern or distribution and good penetration at a moderate range, with light charges of powder—these being the essential requirements of any well-constructed shot-gun.

*The Parker Breech-loading Shot-Gun*, Fig. 1666, is an example of the most approved American construction, and is the manufacture of Parker Brothers of Meriden, Conn. The engraving represents the gun as opened. This is effected by pressing upon the finger-piece 1 in front of the guard 2. The lifter 3 is thus raised, and its beveled side, coming in contact with the screw 4, acts as a wedge to draw the bolt 5 from the mortise which is cut in the lug 6, and releases the barrels as shown, ready for the insertion of the cartridges. It will be observed that when the bolt 5 is back to the position represented, a small hole in the under side of this bolt comes directly over the trip 7, which by the assistance of the small spiral spring 8 is made to enter the hole and so hold the bolt in position. At 11 is shown an improved cartridge-extractor, which draws the shells or cartridges from the barrels during the operation of opening the gun. It is inserted in a hole in the lug 6, with its rear end enlarged and extending into and around a portion of the chambers of the barrels. When the gun is closed, the extractor 11 extends from the rear end of the barrels to the projection on the point 13; and as the barrels swing on this point, which remains stationary, this projection forces the extractor from the rear end of the barrels, so that, when they arrive at the position shown in Fig. 1666, the cartridges are withdrawn from them far enough to be entirely removed by hand. After removing

*Table showing Data of Trials of the Four Magazine Guns which gave best Results at Experiments made at Springfield Arsenal,* 1878.

| NAME OF GUN. | Number of Cartridges Carried. | WEIGHT. | | SAFETY TEST. | | RAPIDITY WITH ACCURACY. | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | As Magazine Gun. | | | | As Single-loader. | | | |
| | | Not Loaded. | Fully Loaded. | Time. | Miss-fires. | Shots. | Hits. | Miss-fires. | Remained in Magazine. | Shots. | Hits. | Miss-fires. | Remained in Chamber. |
| No. | | Lbs. Oz. | Lbs. Oz. | Sec. | | | | | | | | | |
| Hotchkiss...19 | 6 | 9 0 | 9 8 | 19 | .. | 29 | 20 | .. | 5 | 44 | 26 | .. | .. |
| Winchester..13 | 11 | 10 6.5 | 11 6 | 6 | .. | 35 | 22 | .. | 8 | 30 | 24 | .. | .. |
| Remington..17 | 9 | 9 9 | 10 6 | 13 | .. | 34 | 20 | 2 | 2 | 44 | 17 | 1 | .. |
| Sharps...... 8 | 11 | 10 0 | 10 15.7 | 15 | 1 | 27 | 24 | .. | 6 | 41 | 33 | 1 | .. |

| NAME OF GUN. | RAPIDITY AT WILL. | | | | | | ENDURANCE. | | |
|---|---|---|---|---|---|---|---|---|---|
| | As Magazine Gun. | | | As Single-loader. | | | | | |
| | Shots. | Miss-fires. | Remained in Magazine. | Shots. | Miss-fires. | Remained in Chamber. | Shots. | Miss-fires. | REMARKS. |
| No. | | | | | | | | | |
| Hotchkiss...19 | 22 | .. | 1 | 28 | .. | .. | 500 | .. | Gun worked well. |
| Winchester..13 | 28 | .. | 2 | 23 | .. | 1 | 500 | .. | One shell failed to extract. |
| Remington..17 | 10 | .. | 8 | 24 | .. | 1 | 500 | 2 | |
| Sharps...... 8 | 21 | .. | 4 | 26 | .. | .. | 500 | .. | Worked well. |

| NAME OF GUN. | DEFECTIVE CARTRIDGES. | | | DUST. | | | RUST. | | |
|---|---|---|---|---|---|---|---|---|---|
| | Shots. | Miss-fires. | REMARKS. | Shots. | Miss-fires. | REMARKS. | Shots. | Miss-fires. | REMARKS. |
| No. | | | | | | | | | |
| Hotchkiss...19 | .. | .. | Gun worked well... | .. | .. | Gun worked well..... | .. | .. | Magazine cut-off rusted in seat; otherwise worked well. |
| Winchester..13 | .. | .. | " | .. | .. | " | .. | .. | Gun worked well. |
| Remington..17 | .. | .. | Shell burst underneath gas-escape........... | .. | 2 | Cartridges would not feed from magazine....... | .. | .. | ..................... |
| Sharps...... 8 | .. | .. | Gun worked well... | .. | .. | Gun worked well..... | .. | .. | Gun worked well. |

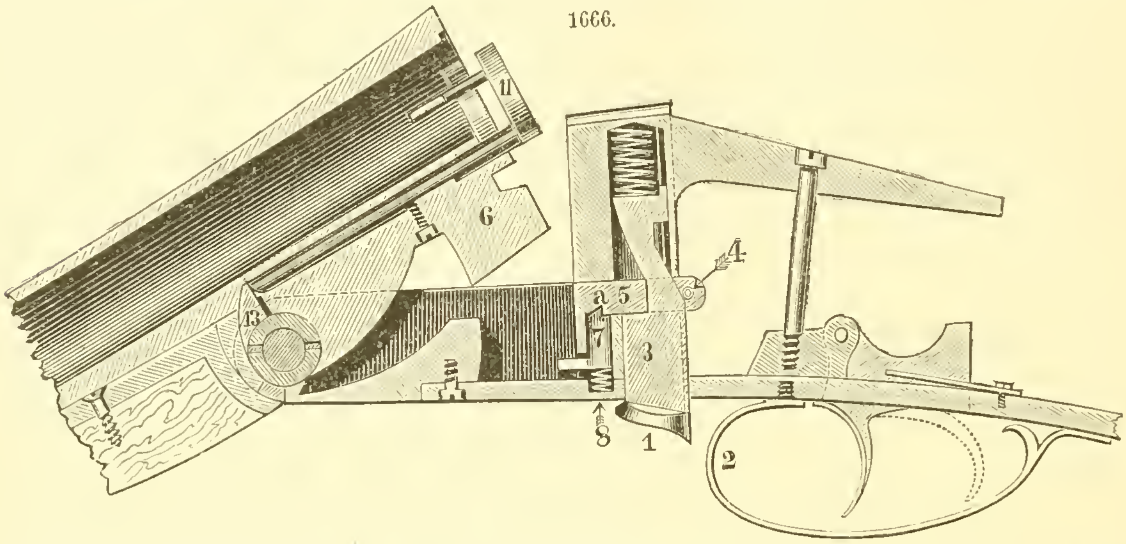
| NAME OF GUN. | EXCESSIVE CHARGES. | | | SUPPLEMENTARY TESTS. | |
|---|---|---|---|---|---|
| | Shots. | Miss-fires. | REMARKS. | Mean time of Firing 20 Rounds by three Enlisted Men. | OF 60 CARTRIDGES FIRED— |
| No. | | | | Min. Sec. | |
| Hotchkiss...19 | .. | .. | Head of shell burst under extractor; worked well. | 1 37 | 43 hit target 6 × 24 inches, 100 yards; 17 hit figure of man at centre of target; others grouped well around it. |
| Winchester..13 | .. | .. | Two shells failed to extract until 2d trial..... | 1 58 | 48 hit target as above; 28 hit figure of man; others well grouped. |
| Remington..17 | .. | .. | ........................... | 2 29 | 47 hit target as above; 15 hit figure of man; others well grouped. |
| Sharps...... 8 | .. | .. | Gun worked well........... | 2 34 | 38 hit target as above; 11 hit figure of man; others well grouped. |

*Table showing Final Test of the successful Gun at Springfield Arsenal Trials*, 1878.

| NAME OF GUN. | MEAN TIME OF FIRING SIX SHOTS, THREE TRIALS. | | |
|---|---|---|---|
| | Piece brought to the Shoulder. | | Fired at Will. |
| | As a Magazine Gun. | As a Single-loader. | As a Magazine Gun. |
| Hotchkiss, No. 19 | 8 seconds. | 16 seconds. | 6 seconds. |
| U. S. Springfield rifle | .......... | 18 " | .......... |

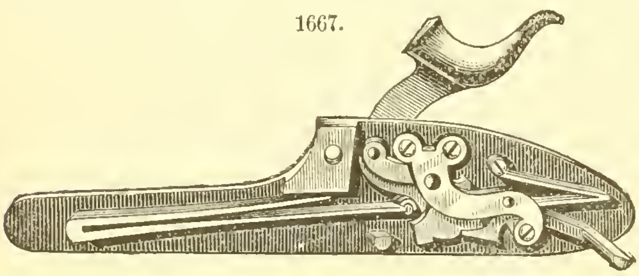
the cartridges and inserting others, the barrels are brought to place, and the cartridges, coming in contact with the face of the frame, are forced into the chambers, when the gun is ready for firing.

1666.




An ingenious form of lock, represented in Fig. 1667, is used on these guns, the object of which is to prevent premature or accidental discharges. When the gun is fired, the mainspring carries the hammer in the usual manner until the spring comes in contact with the stud in the plate and stops. The hammer by its own momentum now explodes the cap, and the nose of the sear then rests on the incline of the tumbler, so that the hammer is thrown back to half cock as soon as the pressure is relieved from the trigger.

1667.



These guns weigh from $5\frac{1}{2}$ to 13 lbs. The dimensions are as follows: length of barrels, 28 to 32 inches, "drop" from $2\frac{1}{2}$ to 3 inches at butt; stocks (from centre of front trigger to centre of butt plate) vary from 14 to $14\frac{1}{2}$ inches. The quantity of powder used varies from 2 to 6 drams, and of shot from three-fourths of

1668.


an ounce to 2 ounces. A coarse-grained powder, about the size of extra-large mustard seed, is to be preferred. (See EXPLOSIVES.)

*The Climax Self-cocking Gun*, Fig. 1668, is of English construction, made by Messrs. Holland of

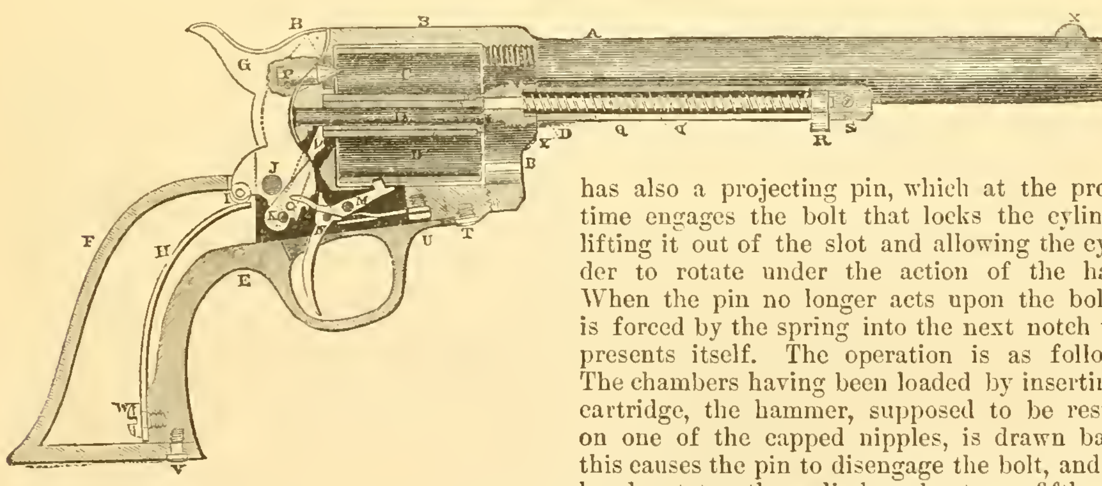
London. It is so constructed that its cocking occurs simultaneously with the opening of the breech, so that only one motion of the lever is necessary to accomplish both these objects. This self-cocking action is produced by means of a lifter *C*, jointed on to the short arm of the lever *A*. The operation is performed by pushing the lever downward; and this opens the bolts of the grip, and at the same time drives up the lifter (which works in a slot in the body), which presses against the extreme end of the hammers *D*, and drives them back either to the half or full cock as may be desired; this is regulated simply by the extent to which the lever under the guard is depressed. When the gun is closed, the head of the lifter, which lies under the hammers and between the nipples, is sunk in the body, and presents an appearance there similar to other guns.

*Rifles.*—Sporting rifles made by manufacturers of military arms differ from the latter chiefly in point of weight and finish, the system of construction being the same. Nearly all American makers publish very full catalogues, which often embody treatises on the manufacture of sporting rifles, and are especially complete in details referring to the weapons used at long-range target competitions. In some of these matches Remington's and Sharps's rifles, of American make, and Rigby's and Metford's, of English make, the former breech-loading and the latter muzzle-loading, have come into direct competition, and the relative efficiency of the two radically different systems has been severally tested, with a preponderance of advantage in favor of the American arms. As the trade publications above referred to contain full reports of competitions in which the various rifles were used, it seems unnecessary to do more than refer the reader to the manufacturers, who supply such information gratis.

One of the most noted sporting rifles of foreign make is the "Express," constructed by the Messrs. Holland of London. This rifle is breech-loading, and is made double-barreled. It is chiefly noted for long range and accuracy. The 577 bore Express takes a charge of 6 drams of powder. Larger sizes take as high as 8 drams, and are commonly used by African explorers against large game. They project hollow-fronted, solid hardened, or explosive bullets.

REVOLVERS.—*Colt's.*—Fig. 1669 represents a sectional view of Colt's army revolver. This has 6 chambers; total length of barrel, 12.5 inches; weight, 2.31 lbs.; weight of powder charge, 28 grains, and of bullet, 230 grains. The various parts are as follows: *A* is the barrel; *B*, the frame; *C*, the cylinder; *D*, the centre-pin; *E*, the guard; *F*, the back strap; *G*, the hammer; *H*, the mainspring; *I*, the hammer-roll and rivet; *J*, the hammer-screw; *K*, the hammer-cam; *L*, the hand and hand-spring; *M*, the stop-bolt and screw; *N*, the trigger and screw; *P*, the firing-pin and rivet; *Q*, the ejector-rod and spring; *R*, the ejector-head; *S*, the ejector-tube screw; *T*, the guard-screw; *U*, sear and stop-bolt spring; *V*, the back-strap screw; *W*, the mainspring screw; *X*, the front sight; *Y*, centre-pin catch-screw; *B'*, the recoil-plate; *D'*, the centre-pin bushing; and *Q'*, the ejector-tube. On the base of the cylinder is a ratchet having as many teeth (5 or 6) as the chamber has barrels. The teeth are so arranged that, when the hammer is at full cock, a chamber is directly in line with the barrel. On the surface of the cylinder are cut as many small slots as there are chambers. That which happens to be lowest at the time is entered by a bolt which is moved by the action of the lock, and is pressed into the slot by a spring, so that while in this position the cylinder is immovable. The sear and trigger are in one piece, as are also the hammer and tumbler *G* upon which the main spring acts directly. On the face of the tumbler is a pawl or hand, *L*, which successively engages each of the teeth on the rear of the cylinder; and the tumbler

1669.

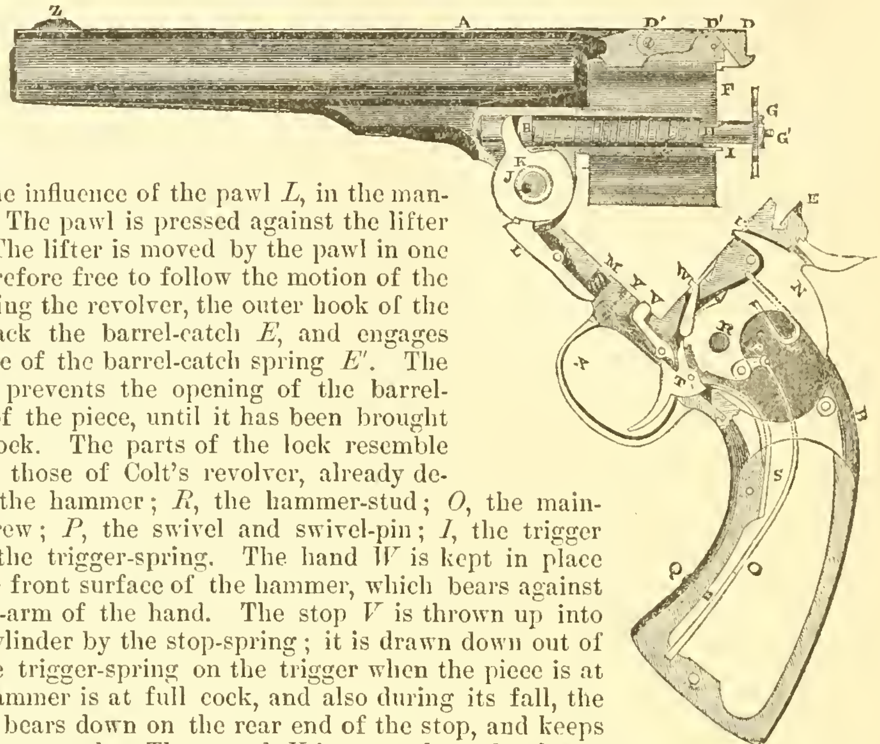



has also a projecting pin, which at the proper time engages the bolt that locks the cylinder, lifting it out of the slot and allowing the cylinder to rotate under the action of the hand. When the pin no longer acts upon the bolt, it is forced by the spring into the next notch that presents itself. The operation is as follows: The chambers having been loaded by inserting a cartridge, the hammer, supposed to be resting on one of the capped nipples, is drawn back; this causes the pin to disengage the bolt, and the hand rotates the cylinder about one-fifth of a revolution. On arriving at full cock the pin is disengaged from the bolt, which then falls into the next slot and locks the cylinder. The weapon is then discharged by pulling the trigger.

*The Schofield-Smith & Wesson Revolver*, Fig. 1670.—This arm has 6 chambers, and for army use the total length of the barrel is 12.5 inches. Its weight is 2.5 lbs.; weight of powder charge, 28 grains, and of bullet, 230 grains. *A* is the barrel, connected with the frame *B* by the joint-screw *C*. From the rear of the barrel projects the base-pin, on which the cylinder *F* revolves. This is kept in place on its pivot by the inner hook of the cylinder-catch *D*. The latter is pivoted at its front end on the cylinder-catch screw *D''*, and is held down by the cylinder-catch cam-screw *D'*, the cutting away of the upper part of the middle portion of which allows the catch to rise when the cam is turned to a certain position. The base-pin is hollow, and contains the extractor-stem *H*, made in two parts, which screw together. Between the head of the stem and the bottom of the hole in

the cylinder is confined the extractor-spring $H'$ (more properly the retractor-spring), which is compressed when the extractor moves out. The extractor $G$ is recessed into the face of the cylinder. The ratchet by which the cylinder is revolved is cut in the face of the extractor, and the extractor-stud $G'$ forms a rear bearing for the cylinder on the frame when the revolver is closed. The steady-pin $I$ keeps the extractor exactly in place when it is down. The lifter $J$ moves upon the friction-collar $K$, under the influence of the pawl $L$, in the manner hereafter described. The pawl is pressed against the lifter by the pawl-spring $M$. The lifter is moved by the pawl in one direction only, and is therefore free to follow the motion of the extractor-spring. In closing the revolver, the outer hook of the cylinder-catch presses back the barrel-catch $E$, and engages with it under the influence of the barrel-catch spring $E'$. The position of the hammer prevents the opening of the barrel-catch, and consequently of the piece, until it has been brought to the position of half cock. The parts of the lock resemble in their general features those of Colt's revolver, already described. They are: $N$, the hammer; $R$, the hammer-stud; $O$, the mainspring; $Q$, the strain-screw; $P$, the swivel and swivel-pin; $I$, the trigger and trigger-pin; and $S$, the trigger-spring. The hand $W$ is kept in place by the hand-spring in the front surface of the hammer, which bears against a flat place on the pivot-arm of the hand. The stop $V$ is thrown up into the stop-motion of the cylinder by the stop-spring; it is drawn down out of them by the action of the trigger-spring on the trigger when the piece is at half cock. When the hammer is at full cock, and also during its fall, the upper arm of the trigger bears down on the rear end of the stop, and keeps its head securely in the stop-notch. The guard $X$ is secured to the frame by the guard-screw $Y$, and by a lip on the rear end of the guard-strap which fits under a projection on the frame. $Z$ is the sight, and $O$ the recoil-plate.

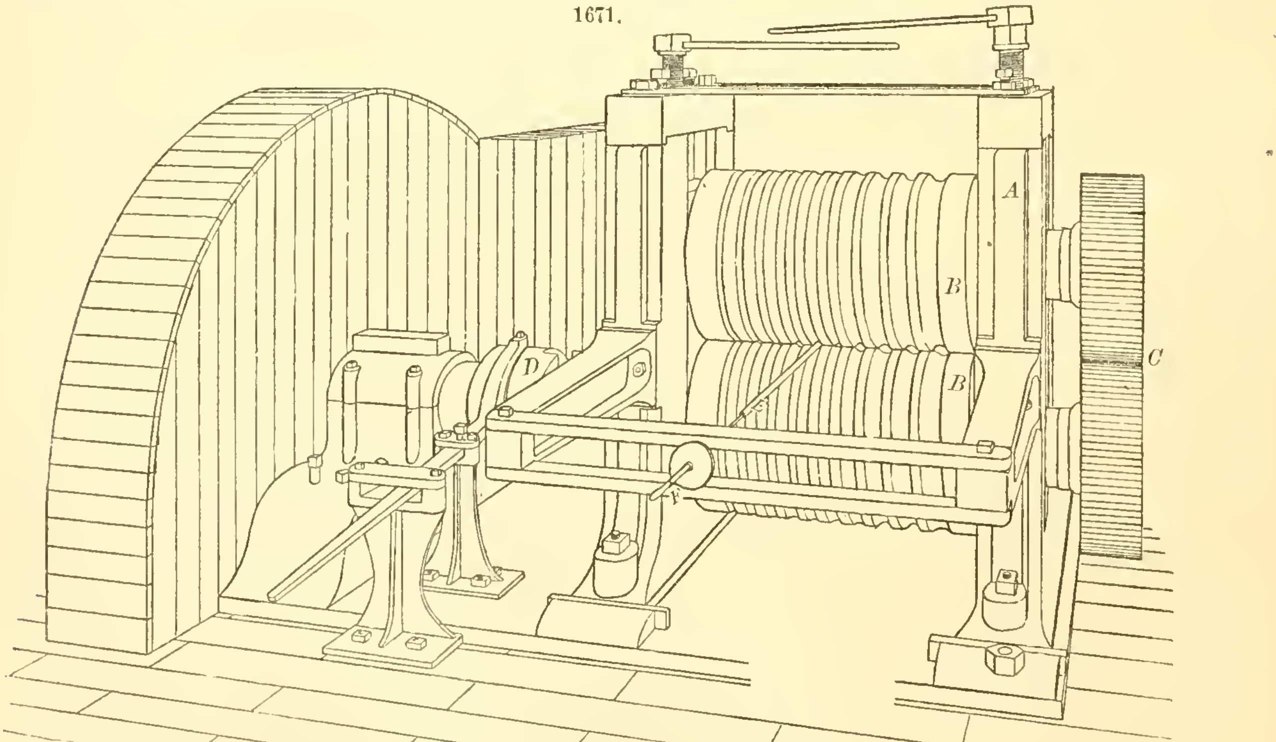
1670.



For full details as to dimensions of revolvers, modes of inspection, etc., see "Ordnance Memoranda, U. S. A.," No. 22 ("The Fabrication of Small Arms").

FIRE-ARMS, MANUFACTURE OF. THE MANUFACTURE OF RIFLES.—The manufacture of rifle-barrels is one involving a great deal of skill and delicate manipulation, for the reason that the length of the bore is so great in proportion to its diameter that the boring appliance, whether drill-reamer

1671.

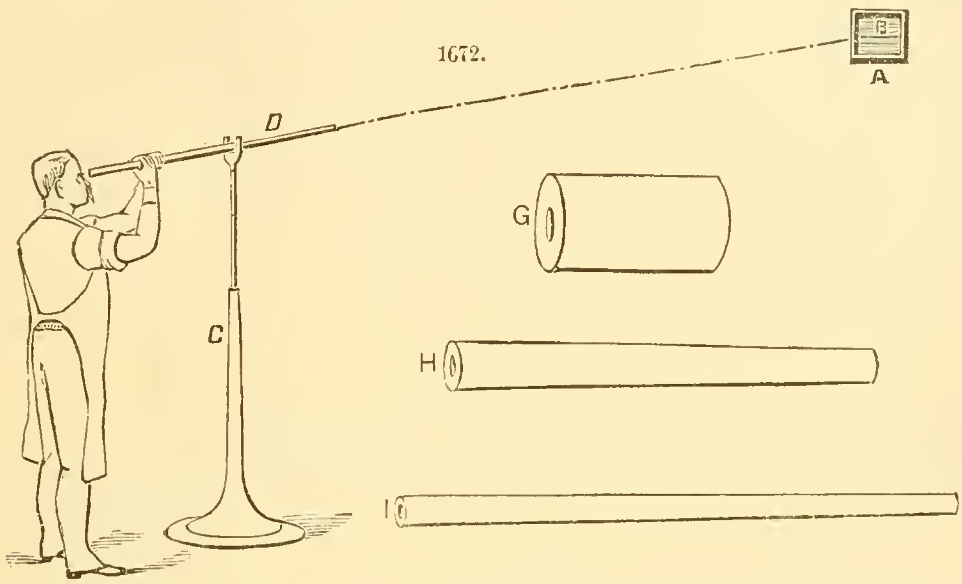



or bit, is exceedingly liable to spring, and will consequently, to some extent, follow the inaccuracies of the hole, even under the most careful manipulation and with the very best tools and machines. To obviate this difficulty has been the object of many inventions, the most prominent among which abroad is probably the hydraulic cold-steel drawing process, in which ingots of cold steel are forced by hydraulic pressure through dies.

The following is the method of manufacture of Springfield rifles in the National Armory at Springfield, Mass. A most minute description of every stage of the various operations will be found in "The Fabrication of Small Arms," in "Ordnance Memoranda, No. 22," by Lieut. Col. J. G. Benton and others, Washington, Government Printing-Office, 1878.

*Barrel-Rolling.*—A Springfield gun-barrel is made from a 2-inch round bar of decarbonized steel. This bar is cut into lengths of 9¼ inches each, and through these holes are drilled, forming what is known as the "barrel mould," represented at *G* in Fig. 1672. This is heated and drawn out between grooved rolls. Each set of rolls, as shown in the engraving, has 8 grooves, 2 cylindrical and 6 taper, and in connection with the grooves 8 mandrels of various sizes are employed. The action of the rolls is to draw the heated mould over the mandrel, when the cylinder is straightened and reheated. Each mould is therefore rolled 8 times. *H* and *I*, in Fig. 1672, show its form at different stages during the process. *A* is the housing, *B B* the rolls, *C* the connecting gears, *D* the clutch, *E* the gun-barrel, and *F* the barrel-rod. While still hot the barrel is cut to the proper

1672.




length by circular saws, and is afterward straightened between two dies, each of the length and shape of the half barrel, which are arranged in a special machine. Annealing in charcoal follows, after which the barrel is straightened on the outside. This done, the boring processes commence, the first one being termed the nut-boring, which is performed as follows:

*Boring.*—The boring-rod or tool consists of a long rod of steel, sufficiently small and long to pass through the hole in the rifle-barrel; on the end of this rod is an enlarged piece about an inch in length, the cutting edges being at the shoulder; the operation is to pass the rod through the rifle-barrel and bore, by the revolving tool being pulled, and not pushed, by the feeding motion. It is obvious that if the resistance to the cut, or the strain caused by the cut, is in a direction tending to compress the metal of the boring-rod, that rod will spring and bend from the resistance; whereas, if the strain is a tensile one, the whole strain due to the cut will tend to keep the boring-rod straight and true, and prevent it from springing, no matter how heavy the cut may be. After the first boring, the rifle-barrel is again bored with another tool similar in every respect, save that it is of larger diameter. The next operation is to straighten the bore, which is performed, as shown in Fig. 1672, as follows:

*Straightening the Bore.*—*A* is a frame containing a plate of ground glass, across which is placed horizontally the small, dark-colored bar *B*, the frame being placed in such a position that daylight shines directly through it; at about 40 feet distance stands the rest *C*, which is to support one end of the rifle-barrel *D*, while the operator ranges the other end direct to the horizontal bar *B*. When the operator adjusts the barrel so that the light from the ground glass shines in a straight line through the rifle-barrel, the bar *B* will throw a dark line along each side of the rifle-bore for a distance, commencing at the end farthest from the operator's eye, about three-fourths the length of the bore. (The rest of the bore appears from end to end like broad rings of light.) It is the straightness of these lines which is a guide to test the straightness of the bore. If there is the least waver, the barrel is not straight; but here arises the difficulty—in that to see the waver inside is a very easy matter, but to locate it on the outside requires such correctness and judgment of vision that not more than one man in ten who essay to learn the business ever attains proficiency. It is necessary to revolve the barrel, so that the dark line shall strike all parts of the barrel, which must also be turned end for end in the rest *C*, because, as stated, the dark lines do not extend from end to end of the barrel. When the location of the bend is determined, the barrel is laid across an iron anvil or block, on which there are two projecting blocks, about 8 to 10 inches apart, and the straightening is performed with an ordinary blacksmith's hammer. After the first straightening, a collar of Babbitt metal is run on the outside and in the centre of the length of the barrel, which collar is faced up true, and used in a steady rest to prevent the barrel from springing while the roughing cuts are being taken off the outside in the lathe; it would be quite useless to finish the bore before the outside was turned, because, the latter operation releasing the tension on the outside of the metal, the inside would get out of true again. After the first outside turning has been per-

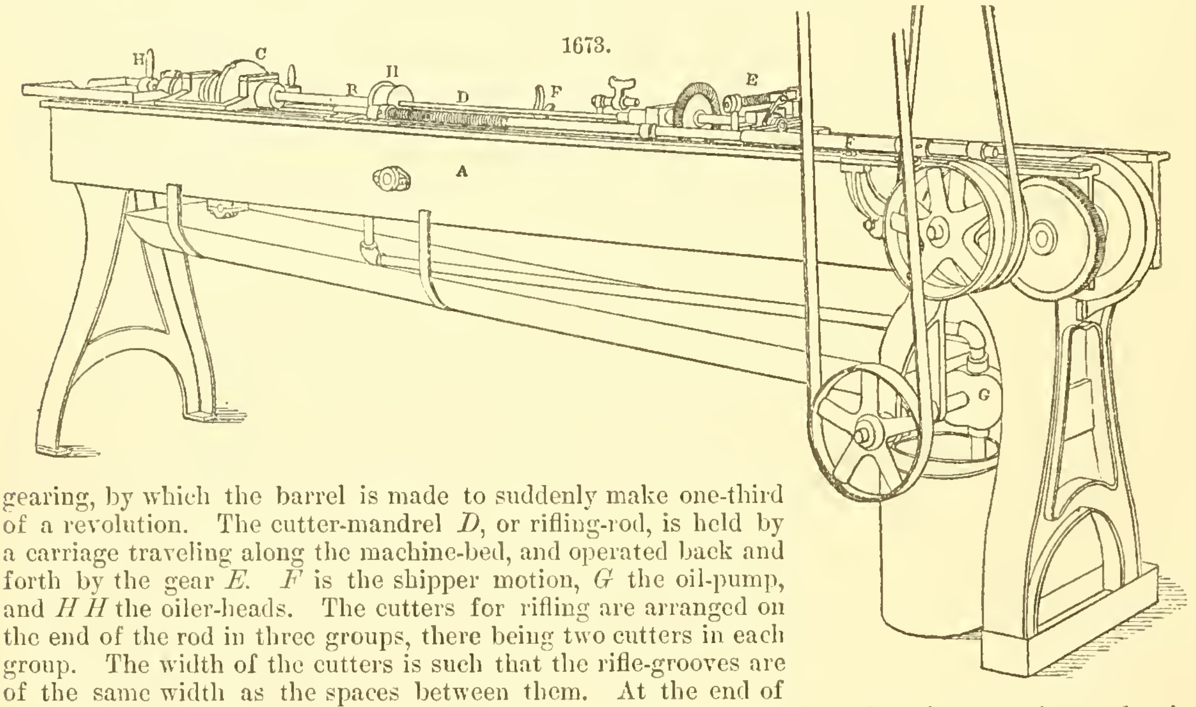
formed, the barrel is again bored, this time with a square reamer, revolved at a somewhat quick speed, and led first forward and then backward and forward somewhat rapidly.

The next operation is to repeat the straightening process, and then the outside is again turned, and the boring process repeated, the same square reamer being used with a piece of wood placed on one square, which piece of wood steadies the reamer, as well as causing it to cut a slightly larger bore, by reason of fitting a little tight in the rifle-bore. After this boring, the outside of the barrel is ground on a quick-running stone, and the straightening and boring processes are repeated, slips of paper being placed under the piece of wood, so as to increase the size of the bore until it becomes of the correct, plug-gauge size. Here we may note that the dark lines thrown on the inside of the bore by the horizontal bar $B$ in the frame $A$ magnify any defect in the bore, and that, as the operatives express it, the wave in the barrel never appears to be where it actually is; and hence the difficulty of locating the defect on the outside of the barrel. Proving takes place at this stage, heavy charges of powder and lead slugs being used; 40 barrels at a time are thus tested.

*Polishing.*—After various milling and filing operations, to square off ends and prepare parts for the sights, comes the polishing of the outside, which is performed as follows: The barrel is held vertically, and revolved while being passed down between the end faces of two pieces of wood, upon which emery has been glued in the same manner as on an ordinary wooden polishing emery-wheel. After the first polishing process, however, the barrel is not made to revolve, but is moved vertically back and forth between the pieces of wood, so as to leave the polishing marks straight lengthwise of the barrel. The first polishing is performed with a grade of emery about No. 60; the last is done with flour emery. The machine in which the polishing is performed holds five barrels at once, the polishing woods opening and closing as the barrel passes through them, so as to accommodate the taper.

*Rifling* is done in the machine illustrated in Fig. 1673. The bed $A$ is similar to that of a lathe, the rifle-barrel $B$ being held in a head $C$ at one end of the bed; to this head is attached suitable

1673.




gearing, by which the barrel is made to suddenly make one-third of a revolution. The cutter-mandrel $D$, or rifling-rod, is held by a carriage traveling along the machine-bed, and operated back and forth by the gear $E$. $F$ is the shipper motion, $G$ the oil-pump, and $H\,H$ the oiler-heads. The cutters for rifling are arranged on the end of the rod in three groups, there being two cutters in each group. The width of the cutters is such that the rifle-grooves are of the same width as the spaces between them. At the end of the stroke the rifling-rod also makes a one-third revolution, but in a direction opposite to that in which the barrel moves when partly revolved; so that each set of cutters cut first in one groove and then in another, by which means the rifling is performed more true than would be the case if the same cutters always ran in the same groove. The cutting is performed on the stroke in which the rifling-rod is being pulled through the rifle-bore, and does not operate when being pushed, because a tensile strain tends to keep the rod straight, while a compressing one would inevitably spring and bend the rod.

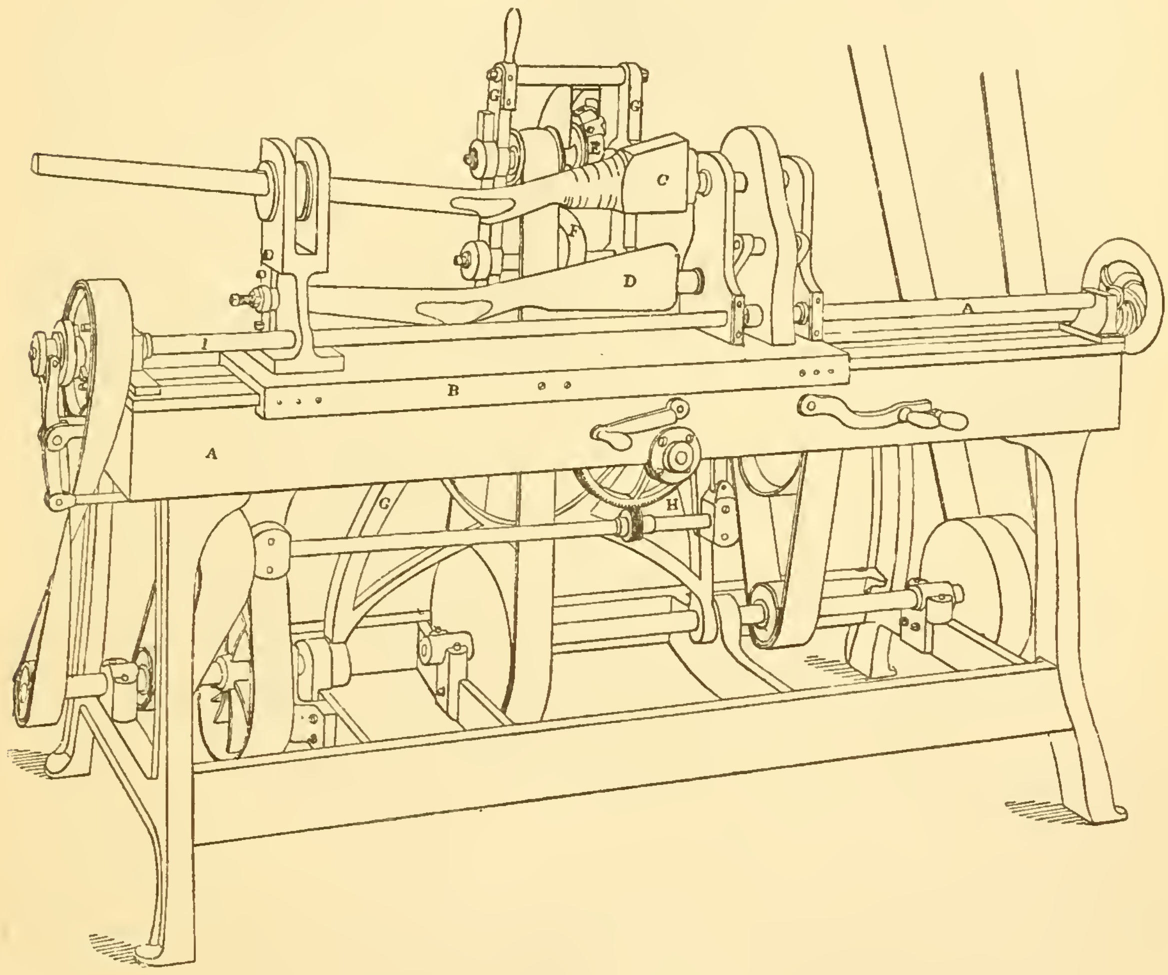
The cutters are ranged so that their cutting edges stand at a right angle to the rifle-groove, and not to the bore of the barrel. They are not in reality cutters, but scrapers. The cutters are expanded as the rifling proceeds by a cone attachment applied to the bar, the feed-motion being on the sliding carriage. When, however, the rifle-grooves have been cut sufficiently deep, which is determined by the amount of the expansion of the cutters, an automatic arrangement, which is very simple in its construction, throws the cutters back to their smallest diameter, and the process ceases. During the whole of the boring and rifling processes, the bore of the barrel is liberally supplied with oil, the tools being tempered to a light straw color.

*Stock-making.*—The rifle-stocks are made as follows: The wood, black walnut, is kiln-dried, and the stock sawn out to the necessary shape, allowing sufficient surplus in the size for the finishing process. In this condition the wood is left to season. The first operation is facing off the stock on the part where the barrel fits. The second is termed the tip-turning; that is, turning the under or outside face of the part where the barrel fits. The stock is then ready for the butt-turning machine or lathe. To drive it, a dog composed of a piece of iron somewhat less in size than the finished end of the butt, and having several protruding spikes on one of its faces, is driven on to the end of the

butt, and this driver fits into a socket which takes the place of the face-plate of an ordinary lathe. In place of a tail-stock, or dead-centre, there is provided a standard fastened to a carriage sliding upon the lathe-bed, the standard containing a washer revolving in a bearing. The washer is made in two halves, one half containing an oval slot to fit the outside or oval face of the tip, the other being flat to fit the face of the part where the barrel fits or rests. The halves of this washer are thrown open; the tip of the stock is passed through them; the butt end with the dog in position is then put into the socket-driving chuck, and held firmly back against it; then the washers are by means of a set-screw clamped to the tip, and the cap securing the washers in the bearing is closed, and the stock or butt is chucked, ready to be turned. The bed *A* of the lathe, Fig. 1674, is similar to an ordinary flat-surface lathe-bed, and upon it there slides a carriage *B*, which carries the standard and the socket-driving chuck with the butt or rifle-stock *C* placed in them, as above described. Immediately below the butt, and held by the same carriage, is a pattern stock or former, *D*, made of cast-iron, and held in the same manner as is the wooden butt, the driving chucks of both being made so that they revolve in the same plane and at the same speed.

Independent of the bed and carriage, and in a permanent position, there is an upright frame *G*, pivoted at the bottom or foot so that the top can swing. In this frame there is a wheel *F*, which revolves against the cast-iron former-butt referred to above, so that when the upright frame is

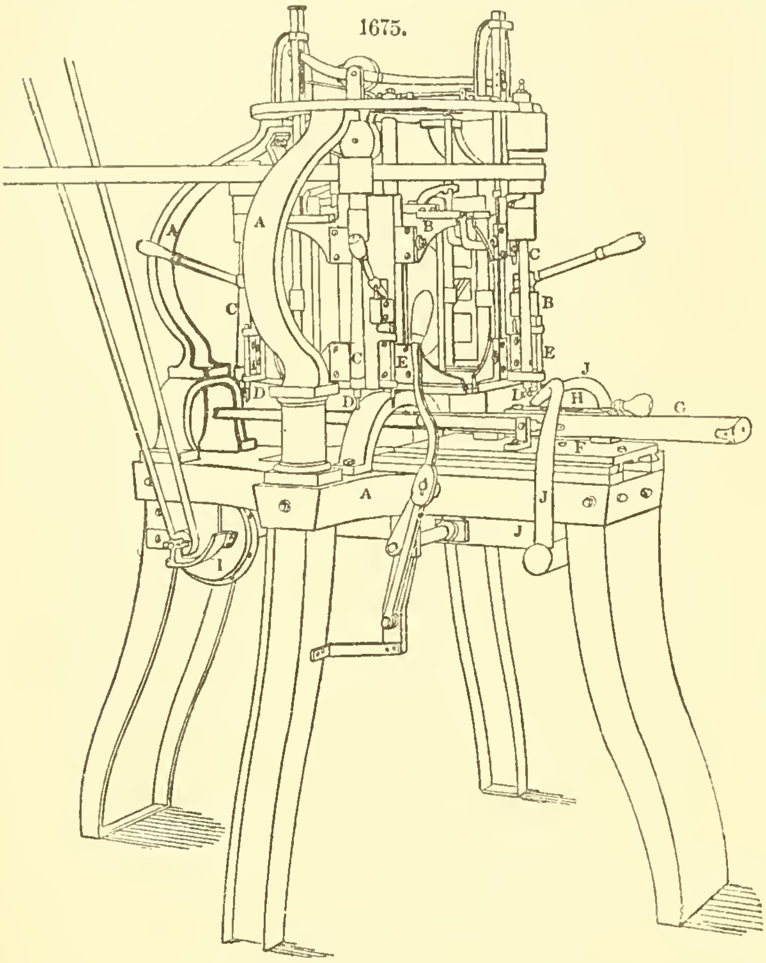
1674.




moved out of the perpendicular its weight presses the wheel against the cast-iron former, and thus causes the frame to partake of the irregular motion caused by the revolving of the iron former-butt. In the same upright pivoted frame is a revolving cutter-head *E*, the distance between the centres of the cutter-head and the wheel referred to (whose bearings are both horizontal and parallel one to the other) being the same as the distance between the centres of the cast-iron former-butt and the wooden butt to be operated upon. *H* is the feed-motion and *I* the shaft for revolving the stock and former. The cutter-head is provided with 12 cutters, arranged in sets of 3, and each taking a different depth of cut. The cutter-head revolves at a speed of 3,600 feet per minute, the cutters all being formed more or less on the turning-gouge principle. The machine being started, the iron former-butt and the wooden one revolve slowly—say at about 80 revolutions per minute; the cutter-head, as above stated, at 3,600 feet per minute. The frame is moved out of the perpendicular, and rests by its own gravity against the iron former-butt, which by friction revolves the guide-wheel. The carriage, which stands all on one side of the revolving cutters, then traverses past them until it stands all on the other side, the whole of the turning being performed during one traverse. The roughing cutters stand in advance on the cutter-head, and the finishing ones, protruding beyond the roughing ones, are placed behind them. The butt-turning process occupies in all about 3 minutes 15 seconds; the whole stock-turning and tip-facing and turning takes 5 minutes; the length of cut taken during the operation being about 13 miles, if placed in a straight line.

*Bedding Machines.*—The rifle-stock now passes to the lock-bedder, which cuts out the recess into which the lock fits. The general appearance of this machine, which is shown in Fig. 1675, is similar to a revolving-head gang-drilling machine, containing 5 spindles *C*, with their cutters *D*. The rifle-stock *G* is chucked in its proper position in a fixed chuck or appliance *F*, which insures that the stock is correctly held; to the right of the stock and in a fixed position is an iron section *H* of that part of the stock into which the lock is bedded, which iron section is used as a guide or former. The machine being started, the first operation is to drill two holes, the drills entering until a stop prevents them from going any further, and hence insuring uniformity and correctness in their depth. The position of these holes is regulated by a pin, which stands the same distance from the drill as is the centre of the recess in the iron former from the required centre of the recess for the lock in the stock being operated upon. The pin reaches the iron former a little in advance of the drill reaching the rifle-stock, so that the position can be accurately set by swinging the machine-head until the guide-pin enters the hole in the iron former; then the drill is fed to its duty by hand. One hole being drilled, the spindles carrying the drill and the guide-pin, which spindles are in the same frame and operate together, are raised, the machine-head is swung one-fifth of a revolution, and the first cutter *D* comes in position to operate. On lowering the cutter-spindle there descends with it, and slightly in advance of it, a guide-pin *E* in the iron former; and when the guide-pin is well within the iron former, the cutter reaches the surface of the wood, and is guided by the operator moving the head so that the guide-pin travels all around the edge of the recess in the former. The motion of the guide-pin and of the cutter being laterally identical, the operator has but to enter the cutter as far into the rifle-stock as a stop provided for the purpose will admit, and then to move the frame carrying the guide-pin and cutter so that the guide-pin moves and touches all around the sides of the recess in the iron former. The recess in the rifle-stock will be then the exact counterpart, in size, form, and depth, of that in the pattern. The whole operation is but a repetition of the above, with the remaining cutters swung one after the other into position, the one iron former answering to regulate the lateral movement of them all. *A* is the frame of the machine; *B*, revolving cutter-head; *I*, a fan-blower; and *J*, the air-pipes leading therefrom. The speed at which the cutters revolve is about 8,000 revolutions per minute. As soon as each drill or cutter is swung out of position, it stops running, which prevents wear and tear. It is apparent that grinding the revolving cutters (which cut on their sides as well as on the end faces) to resharpen them reduces their diameter, and would, unless some provision were made for it, destroy the correctness of the work. This provision exists in the machine by the following means: In the spindles for driving the cutters there is a socket which will partly revolve, but which can be locked or retained in any position. When a cutter is new, and is consequently of full size, it revolves centrally in the socket; but after it has been reduced in size by resharpening, the socket is moved in its position in the spindle by being partly revolved. This causes the cutter to be sufficiently eccentric to the spindle to make up for its lack of correctness in diameter. As a guide in setting the amount of this eccentricity, the spindle is marked into 10 divisions, each being denoted by a line which extends down to the junction of the socket and the spindle end. Upon the socket there is also marked a line, so that this one line acts as a pointer and the other 10 as a rule. To cut out a recess, complete and ready to receive a lock, occupies about a minute. This machine affords a superior specimen of designing, performing many and very accurate operations with great exactitude, and being very simple to operate.

1675.




The guard-bedding machine and the machine for bedding the stocks to receive the barrels operate in substantially similar manner to the lock-bedder, and therefore need no separate description. Numerous other machines are employed, notably milling-machines for various purposes, boring apparatus, screw-threaders, hammers, etc., all of which are adaptations of standard forms of these devices. For descriptions the reader is referred to the work previously quoted. The various portions of the weapon are finally assembled, when it is subjected to proofs and inspection.

The Manufacture of Smooth-Bores.—Every best finished gun usually passes through 15 or 16 hands, each of which constitutes almost a distinct trade; although two or three branches are often combined, or subdivided according to the extent of business. They may be arranged in the following order: 1, barrel forger; 2, lock and furniture forger; 3, barrel borer and filer; 4, lock filer; 5, furniture filer; 6, ribber and breecher; 7, stocker; 8, screwer-together; 9, detonator; 10, stripper and finisher; 11, lock finisher; 12, polisher and hardener; 13, engraver; 14, browner; 15, stock polisher. The barrel-making is also divided into several branches.

The first process in the manufacture of musket or common barrels, is the making what are technically called *skelps*. The skelp is a piece of iron about a foot long, but thicker and broader at one end than at the other; and the barrel of a musket is formed by forging out such pieces to the proper dimensions, and then folding or bending them round into a cylindrical form until the edges overlap, so that they can be welded together. It is then placed in a furnace, raised to a welding heat, and taken out, when, a triblet or cylinder of iron being placed in it, it is passed quickly through a pair of rollers. The effect of this is that the welding is performed at a single heating, and the remainder of the elongation necessary for bringing it to the length of a musket-barrel is performed in a similar manner, but at a lower temperature. This method of welding is far less injurious to the texture of the iron, which is now exposed only once, instead of three or four times, to the welding heat.

The barrels for fowling-pieces are of various kinds, as *stub*, *stub-twist*, *wire-twist*, and *Damascus-twist*, and sometimes a combination of the two latter ones, as well as another description called *stub Damascus*. These are the best varieties, but a number of inferior kinds are made, which are only employed for very common guns.

In order to make stub-iron, old horse-shoe nails, called *stubs*, are collected, then packed closely together, and bound with an iron hoop, so as to form a ball about 10 or 12 inches in circumference; which, being put into a furnace or forge-fire, and raised to a welding heat, is united by hammering, and drawn out into bars of convenient lengths, for the purposes intended. This method is adopted for the locks, furniture, and breechings of all best guns, and is to a certain extent practised for barrels, though not so much as formerly, more expeditious methods being employed on a large scale. The most approved modern method of converting them into gun-barrels (after carefully sorting and picking them, to see that no cast-iron or impurities are mixed with them) is first to put about half a hundred weight into a large cast-iron drum or cylinder, crossed internally with iron bars, through the centre of which a shaft passes, which is connected by a strap with the steam-engine, and the revolution of the drum actually polishes the nails by their friction against each other; they are then sifted, by which every particle of dust is removed. The steel intended to be mixed with them is clipped by means of large shears, worked by the engine, into small pieces, corresponding in size to the stubs, and afterward cleansed by a similar process. About 40 lbs. are thrown on the inclined hearth of an air-furnace, where they are *puddled* or mixed together with a long iron rod, and withdrawn in a mass called a *bloom*, almost in a state of fusion, to be welded under a hammer of 3 tons weight, by which it is formed into a long square block; this, being put in at another door of the same air-furnace, is raised to a bright-red heat, and drawn out under a tilt-hammer of 1½ ton weight into bars of a proper size to pass the rollers, by means of which it is reduced to rods of the required size. The air-furnace having two doors prevents any loss of time, as the moment one ball of stubs is withdrawn, another charge is put in, and the two operations go on together, keeping both hammers employed. The iron thus produced is very tough, and free from specks or grays; but stubs are hardly ever used alone, as they were formerly, being too soft; therefore a portion of steel is mixed with them, which varies from one-eighth to one-half of the whole mass. It need hardly be remarked that the advantage to be derived from the use of horse-shoe nails does not arise from any virtue in the horse's hoof, as some have imagined, but simply because good iron is, or ought to be, originally employed for the purpose, otherwise the nails will not drive into the hoof; and the iron, being worked much more, is freed from its impurities, which can only be effected by repeated workings.

When gun-barrels are manufactured from stub-iron by a process similar to that of musket-barrels, they merely exhibit a mottled appearance on the application of acids. It is also usual to make what are called *stub* barrels from scrap iron cut into small pieces by means of shears worked by the engine. It would be difficult to define what scrap iron is, or what it is not, being composed of everything in iron that has previously been manufactured, as well as of the cuttings from the various manufactories; these are sorted and employed in preparing iron of various qualities, known by the names of *wire* twist, *Damascus* twist, *stub* twist, *charcoal* iron, *threepenny skelp* iron, *twopenny skelp*, etc. The object of preparing iron from small pieces is to cross and interweave the fibres in every possible direction, and thus greatly to increase its tenacity. Very few plain stub barrels are now made, as iron of inferior quality, when twisted, finds a more ready sale. For the finest description of barrels, a certain proportion of scrap steel, such as broken coach-springs, is cut into pieces and mixed with the iron by the operation called puddling, by which the steel loses a considerable portion of its carbon, and becomes converted into mild steel, uniting readily with the iron, and greatly increasing the variegation and beauty of the twist. In whatever manner the iron may be prepared, the operation of drawing it out into ribbons for twisting is the same. This is effected by passing the bars while red-hot between rollers, until extended several yards in length, about half an inch wide, and varying in thickness according to whichever part of the barrel it may be intended to form; these ribbons are cut into convenient lengths, each being sufficient to form one-third of a barrel; one of these pieces is made red-hot and twisted into a spiral form, by placing one end in the prong of an iron rod which passes through a frame, and is turned by a handle, the ribbon being prevented from going round without twisting by means of an iron bar placed parallel to the revolving rod. The spiral thus formed is raised to a welding heat, and dropped on to a cylindrical iron rod, which being struck forcibly on the ground (*jumped*), the edges of the spiral unite, and the welding is then completed by hammering

on the anvil: the other spirals are added according to the length of the barrel, and the forging is finished by hammering regularly all over. The ends of each spiral should be turned up and united at each junction of the spirals, to avoid the confusion in the twist occasioned by merely dropping one spiral on another; but this is rarely done. Wire-twist, of any degree of fineness, may be obtained by welding alternate laminæ of iron and steel, or iron of two qualities, together; the compound bar thus formed is drawn into ribbons, and twisted in the same manner as the preceding. The operation of twisting the iron not only increases the beauty of the barrel, but adds considerably to its strength by opposing the longitudinal direction of the fibres to the expansion that takes place in the act of firing. The iron called *Damascus*, from its resemblance to the celebrated Oriental barrels and sword-blades, is now manufactured by welding 25 bars of iron and mild steel alternately, each about 2 feet long, 2 inches wide, and a quarter of an inch thick; and having drawn the whole mass into a long bar, or rod, three-eighths of an inch square, it is then cut into proper lengths of from 5 to 6 feet; one of these, being made red-hot, is held firmly in a vise, or in a square hole, to prevent it from turning, while the other end is twisted by a brace, or by machinery, taking care that the turns are regular, and holding those parts which turn closer than others with a pair of tongs; the rod is by this means shortened to half its original length, and made quite round. If only two pieces are employed to form the ribbon, one is turned to the right and the other to the left; these, being laid parallel to each other, are united by welding, and then flattened; but if three square rods are used, the centre one is turned in a contrary direction to the outside ones, and this produces the handsomest figure. By these operations the alternations of iron and steel change places at every half revolution of the square rod composed of 25 laminæ; the external layers winding round the interior ones, thus forming, when flattened into a ribbon, irregular concentric ovals or circles. The fineness of the Damascus depends on the number and thickness of the alternations; and the figure of the ribbon when brought out by acids resembles that of a curled ostrich feather; but when wound into a spiral form, and united on its edges by jumping, the edges bend round and the figure is completed. This is sometimes veneered on common iron; and they often wind a thin ribbon of Damascus, or superior iron, round iron of the worst quality; even gas-tubing is considered good enough, when coated in this manner, to form gun-barrels of a very low price with a high-priced appearance. Stub Damascus is merely one square rod of Damascus iron twisted and flattened into the ribbon for forming the barrel. Damascus and wire-twist is a ribbon of each, twisted together to make a greater variety; but there is no quality so good as the best regular *stub-twist.* The Swedish iron, known by the mark C C N D, and coach-springs, form an excellent combination for Damascus barrels.

The next operation is rough boring, usually by machinery. A long square bit, attached to a rod, revolves with great rapidity, while the barrel is pressed forward by a crooked lever, one end of which the workman holds, and passes the other end along a series of nails or pegs, driven into the top edge of the trough or bench on which the barrel is placed, thus forcing the barrel forward along the boring-bit. Water is kept constantly flowing over the barrel during the process, otherwise the heat generated by the friction would soon soften the bit and render it useless. The outsides are then ground on very broad stones turned by the engine. The workman sits on a kind of wooden horse, firmly chained to the floor; a sloping board, nearly in contact with the grindstone, is placed before him, against which he leans, and rests the barrel; a long iron rod passes through the barrel, and projects at each end, sufficiently to form handles, and at the same time an axis, on which the barrel rotates more or less freely, according to the degree of pressure against the board. By moving it regularly sideways, the whole surface is ground over. It is evidently impossible to finish barrels with any great accuracy on a grindstone, though most of the barrels that are made into guns in Birmingham are merely smoothed up after this process, an appearance of regularity being given to them at the muzzle by filing; but if transverse sections were made at different distances, they would be found very unequal in substance, as is always the case with musket and other common barrels, although some of the grinders are able to finish with considerable accuracy. It is in the ground and rough-bored state that most of the best barrels are sent to the finishing gunsmith, where, after being set perfectly straight, they are fixed on a movable carriage, which is drawn gradually forward along a level surface or railway, by means of a weight and pulleys; the boring-bit being fixed in a square hole in the axis of a fly-wheel which is turned by hand or by steam machinery, while the barrel slowly advances until the bit passes out at the opposite end to that at which it entered. The same square bit is made to enlarge the bore to the required size by the addition of a *spill*, which is simply a long thin piece of wood slightly taper, flat on one side and round on the other; this, being placed along one side of the bit, causes it to cut on two angles only, and the size of the calibre may be very gradually increased by the interposition of strips of writing-paper between the spill and the bit. After the barrel is correctly bored, the external part is turned in a lathe, a steel mandrel being introduced at each end. The barrel is thus rendered perfectly correct and equal in every part. The barrel, being *tapped*, that is, screwed at the breech end, and the plug fitted, is now proved with a charge of powder proportioned to the weight of a leaden ball that fits the bore; this is always five or six times the ordinary load; beside which, it is forced with water, as minute defects, invisible to the eye and not affected by the proving, are thus easily detected. When *false-breeched*, *ribbed*, *stocked*, and *screwed together*, the barrel is bored for shooting, and smoothed outside. Double barrels have a flat struck along the inner side of each, previous to laying them together; about 4 inches of the breech end is brazed or hard-soldered, and the remainder of the length soft-soldered; the upper and under ribs being soldered on at the same time.

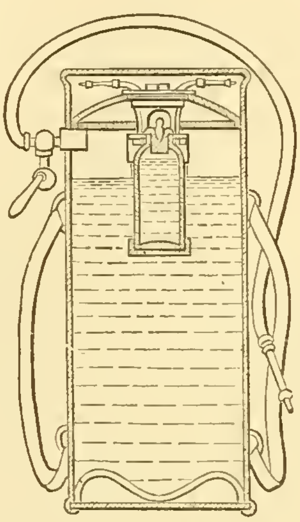
The progressive stages of best gun-making may be briefly enumerated in the following order, supposing the lock and barrel to be already made: The lock and barrel, being jointed to each other (if the plan require it), are given to the stocker, who lets them into the wood, which ought to have been previously cut out of the plank at least two or three years, in order to be perfectly seasoned. The next workman is the screwer-together, who lets in all the furniture and puts in all the screws; when

this is done, the gun is detonated by another workman, who fits the cock, and finishes the external part of the breeching. The barrel then goes to the barrel-maker to smooth and bore for shooting, and the gun is returned to the screwer-together. From him it passes to the stripper and finisher, who takes the whole to pieces and corrects any trifling errors of preceding workmen. The barrel is engraved and browned—an operation performed by producing successive coatings of rust on the surface, and brushing them off as they arise with a fine steel-wire scratch-brush, until the required color is obtained, which usually takes a week, and is effected by a solution of metallic salts, combined with nitric ether; during this process the lock and furniture are polished, engraved, blued, and hardened, and the stock is oiled and polished. The hardening is performed by stratifying the various parts in an iron pan with animal charcoal, prepared from bone- and ivory-dust, or old shoes; the whole is then exposed to a full red heat for about an hour, or according to the size of the work; the pan is withdrawn from the fire, and the contents are thrown into water. The surface of the iron becomes converted into steel by the absorption of the carbon, and beautiful colors are produced, the variegation of the color being affected by the quantity of the iron. The finisher then completes the gun.

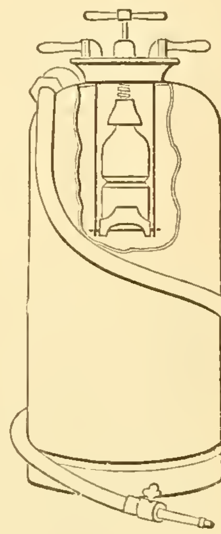
FIRE-ENGINES. See Engines, Fire.

FIRE-EXTINGUISHERS. Nearly all modern special apparatus for the extinguishment of fire is based on the use of carbonic-acid gas. This gas is heavier than air, and when projected upon the flames it cuts off the supply of oxygen which supports combustion. Five per cent. of the gas in the ordinary atmosphere is sufficient to check fire.

1676.



1677.

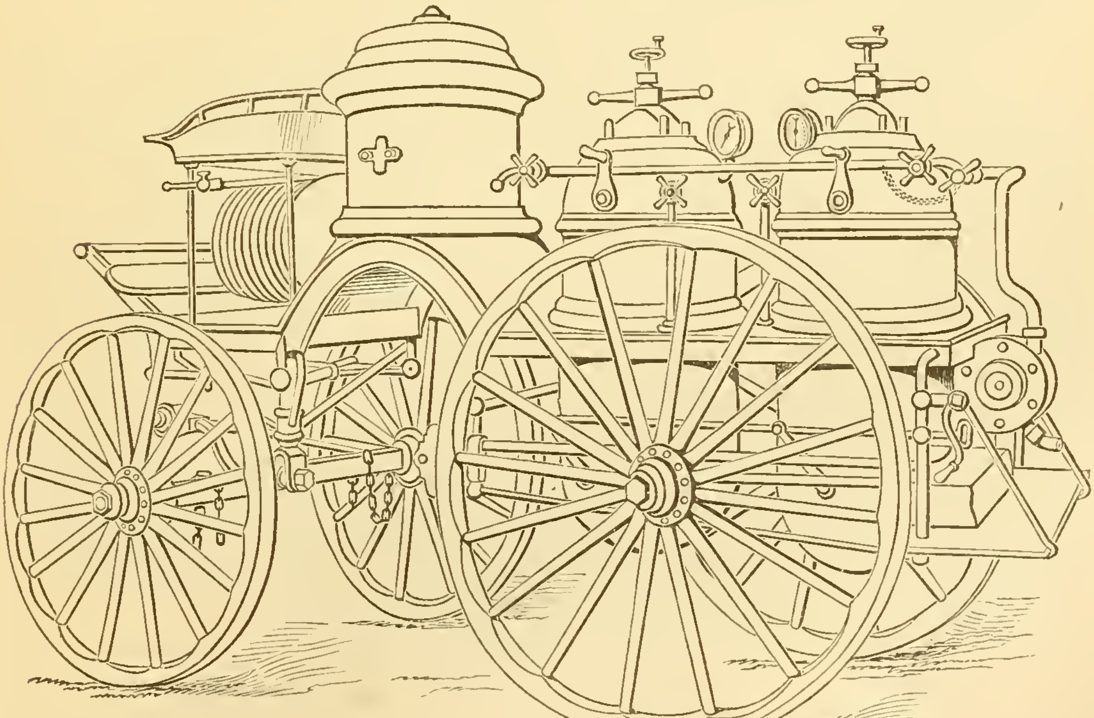


Portable fire-extinguishers differ only in the mechanical construction whereby the chemicals which generate the carbonic-acid gas are brought together.

The Champion Fire-Extinguisher is represented in Fig. 1676. The mouth of the acid-jar is above the water-line. The lead stopper is held by its own weight in the mouth of the glass acid-jar. It is plain that, by simply inverting the machine, the stopper will fall out of the mouth of the acid-jar and allow the acid and alkaline water to come together at the base below the faucet, instantly producing a force of 100 lbs. to the square inch. The power thus obtained, it is claimed, will throw a stream fully 50 feet.

The Babcock apparatus, illustrated in Fig. 1677, contains sulphuric acid in a glass bottle placed in a support, as shown. The alkali is dissolved in water, which fills the extinguisher to within 3 inches of the top. The bottle, after being

1678.

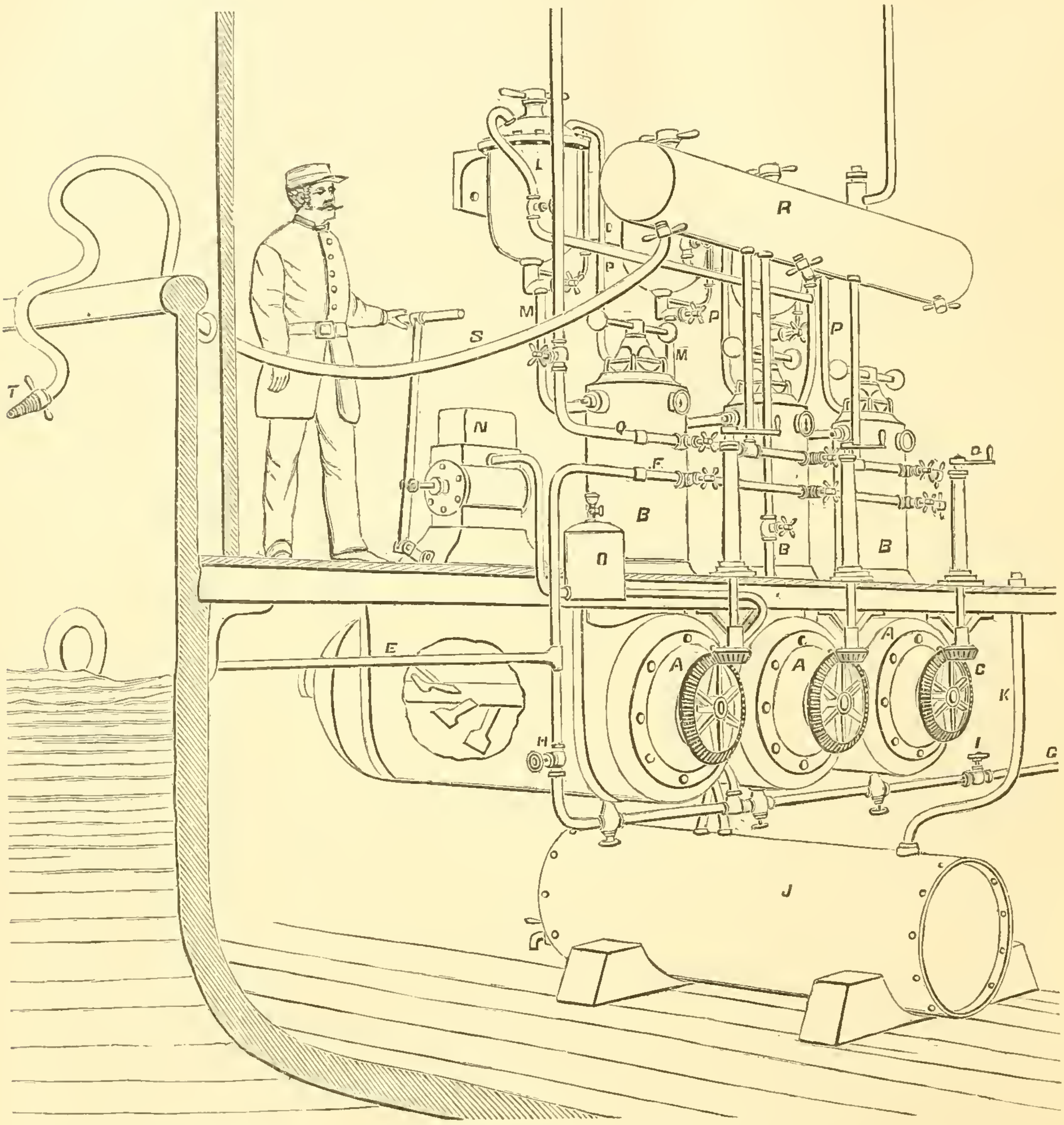


filled with acid, is held by the screw-cap which comes down over its neck. In case of fire, the handle is screwed up. The bottle, no longer held in upright position by the cap, at once turns over, so that

the acid is discharged into the carbonated water. Instantaneous chemical action takes place, supplying about 90 lbs. pressure to the square inch to throw the mingled stream of water and gas.

The arrangement of two large extinguishers of this type, so as to form a chemical fire-engine, is illustrated in Fig. 1678. One cylinder is recharged while the other is working. At a test of one of these engines before the Fire Commissioners of New York, 300 feet of hose was led from it over

1679.



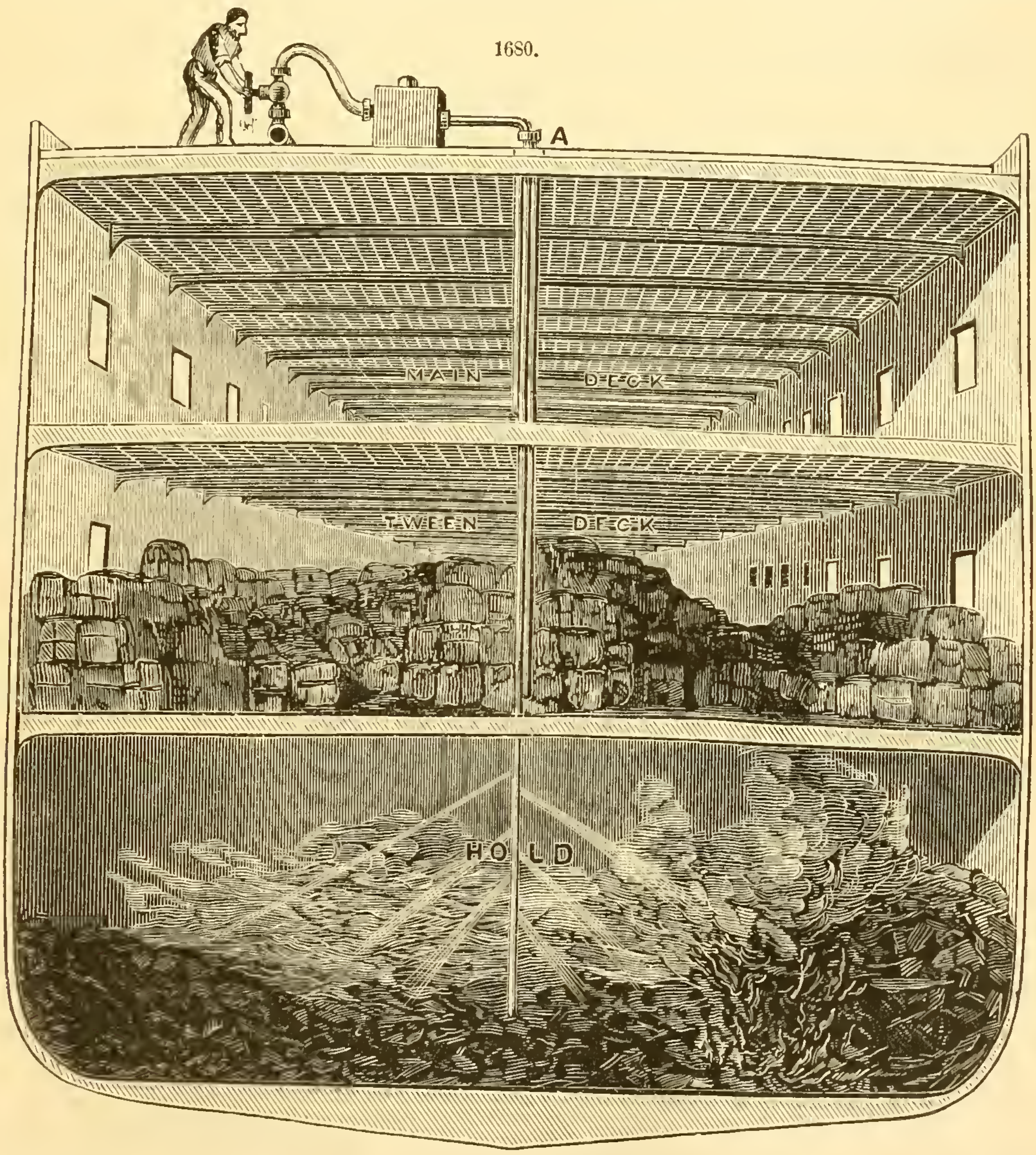

the roof of an engine-house, and thence to the top of a bell-tower 100 feet high; the pressure was turned on at the engine, and a stream was thrown through the 300 feet of hose, from the top of the bell-tower, over the adjoining buildings into the street. It is well known that the most powerful steamer throws a comparatively feeble stream when the hose is led to the top of a lofty building. This is owing partly to the friction in the hose, the weight of water, and, most of all, the fact that all the propelling force is behind the water at the steamer. In the chemical engine it is claimed that any pressure can be obtained, and the propelling force goes out with the stream, thus always giving nearly the same pressure at the nozzle, which pressure can be regulated by merely turning a valve.

One of the most successful applications of carbonic-acid gas to the extinguishment of fires on shipboard, or among shipping in a harbor, has been devised by Mr. A. M. Granger of New Orleans. The general principle on which the apparatus, Fig. 1679, is based, is the direct use of the dry gaseous carbonic acid in smothering volume, in contradistinction to the ordinary employment of limited quantities of the gas dissolved in water under pressure. The generators *A* are copper cylinders, capable of withstanding some 300 lbs. pressure, lined with tin to resist the acid, and suspended by straps under the deck-beams. These vary in number, according to the requirements of the size of the ship, and preferably are about 26 inches in diameter by 9 feet in length, so that each holds about 448 lbs. bicarbonate of soda mixed with water to a paste. Domes *B* extend upward from the generators to a height of 36 inches, and through these the chemicals are admitted. In each generator (as shown by the broken-away portion of one) is a horizontal shaft on which agitating vanes are spirally disposed. When these shafts are rotated, by means of the bevel-gearing *C* and cranks

$D$, a slowly moving current of acid is carried through the soda, and thorough mixing insured. Opening outboard is a water-supply pipe $E$, which communicates with two branch pipes, $F$ and $G$, respectively above and below the generators. The pipe $F$ serves to conduct water to the latter. The pipe $G$ may be used as a waste-pipe, as it leads outboard on the other side of the vessel; or when the valve $H$ is opened, and the valve $I$ closed, it conducts water from $E$ into the cylinders from below, to break up the caked residuum before discharging the same overboard. The acid reservoir $J$ is firmly secured on the bottom of the vessel. It is thus situated apart from the other machinery, so that the corrosive action thereon of its contents is avoided; while, if it should leak, no harm would be done, as the acid would simply run into the bilge. The cylinder, which has a capacity of 213 gallons, is made of quarter-inch lead reinforced by an iron shell, which, while strongly backing and holding the weaker metal, may be easily removed when the inner case needs repairs. The reservoir is charged from the deck above through the pipe $K$. The vessels $L$ are intermediate and distributing receptacles, to hold the acid in small amounts until needed, and also to apportion the charges to the respective generators. They are of copper, lead-lined; they possess gauges for showing the level of their contents, and are directly connected with the domes $B$ by pipes $M$. To fill these vessels, a pipe is provided which extends into and near the bottom of the acid reservoir. From this, branch pipes lead to the separate chargers. An air-pump, $N$, the lever of which is shown in the hands of the figure, forces air by a small pipe into the acid cylinder; and the pressure generated drives the acid up through the conduits and into the chargers $L$, in quantities as desired. Valves are provided, so that one or all of the chargers may be filled. The alkali generators have like valves in the water-pipes, so that water may be admitted to as many as needed.

The carbonic-acid gas may itself be used for forcing up the acid by causing the pressure generated

1680.

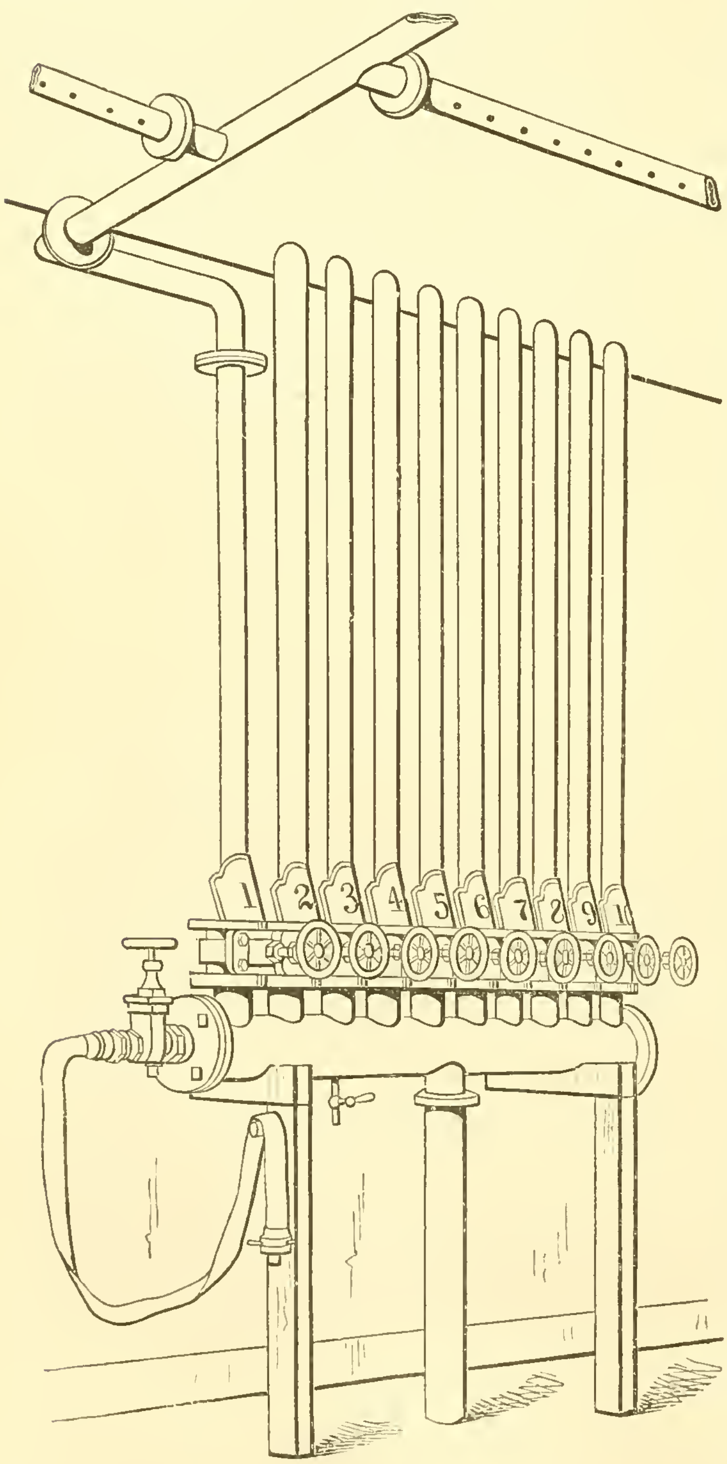



in a portion of the apparatus to act so as to drive the liquid up into the other parts. This is done by a simple adjustment of valves and connections which need not here be explained. Steam may also be conducted to the acid reservoir to serve the same purpose. A water-trap, $O$, is provided in the air-pump pipe, which prevents the acid fumes from injuriously affecting the working parts of the pump. The pipes $P$, connecting the domes with the charges, serve to equalize the pressure between

the two, and to permit the free passage of the acid down to the generator, when the chemicals are to be mixed, by preventing a vacuum above the acid. Each dome, by means of a horizontal distributing pipe *Q*, with suitable vertical branches, communicates with the gas holder or purifier *R*, into which the generated gas is thus conducted. The purifier is a cylindrical vessel, which is imperforate at the points where the entering gas strikes it in issuing from the branch pipes; and between these pipes it is perforated to admit the passage of the gas. The object of this partition is to eliminate the solid and liquid particles which are mechanically carried up in the form of spray, by causing them to impinge against the imperforate portion of the diaphragms. The gas then passes to the hose *S*.

In order to remove the collected impurities from the purifier, a pipe, with suitable valve, leads from the bottom thereof to the discharge-pipe *G*. In this way, water may be led in from the main supply *E*, and also discharged through the same pipe. The latter also serves as a drain for any of the liquid contents of the generator which might surge up into the holder; and thus it operates as an equalizer to restore the said liquid to the generators. In order to introduce the gas into the burning vessel, without causing it to entrain air with it, the nozzle *T* has a tapered screw-threaded swiveling sleeve, which is provided with handles, and which may be screwed into a hole of any size bored in the deck. An attendant at the nozzle is thus dispensed with, and the latter is firmly held air-tight. An extra pipe is connected to the distributing pipe, and leads into the open air so as to prevent the escape of the gas into the room through the safety-valves. There is a separate safety-valve on each dome, and also one on the purifier, which is arranged to blow off into the atmosphere at a lower pressure than those on the domes, in order to insure that no gas shall escape between decks. Pressure-gauges are also arranged on each generator, and one is provided to indicate the pressure applied upon the acid in the reservoir.

1681.




An English inventor, Captain W. H. Thompson, has succeeded in perfecting a device, illustrated in Fig. 1680, that has secured the indorsement of the directors of the "White Star Line" of steamers, upon two of which the apparatus has been fitted. At a point, *A*, on the upper-deck midships, a series of four iron pipes project, and are, when not in use, closed by screw-caps. The pipes terminate below respectively in the main-deck, 'tween-deck, hold, and coal-bunkers. To the right of this line of projecting pipes is a second single one leading from the boilers below, and half-way between this steam-pipe and the other four is a large box, in which carbonic-acid gas can be generated by some one of the usual methods. The reagents needed to generate the gas are then brought together in the box, and connection between it and the nozzle of the pipe leading to the bunkers is established, as here shown. When all is in readiness, the steam-valve is opened, and at once a blast of steam enters the box, where it combines with the carbonic acid, and these two powerful agents rush on and downward together. The carbonic acid, aided by the energy imparted to it by the steam, soon finds its way to the seat of the conflagration, and, replacing the air that favored the combustion, acts as a wet blanket, smothering and finally extinguishing the flames. In order that the distribution of the steam and gas may be as general and positive as possible, the conducting-pipes, on entering their special precinct, are perforated along their sides, the steam emerg-

ing from these holes in the manner indicated in the illustration. It will be seen from the method of its construction that this apparatus is so contrived that either gas or steam may be used alone.

*Hall's System of Fire-Extinguishing Apparatus* is adapted to carrying a supply of water to all portions of a factory by means of pipes, through perforations in which it is discharged at any desired point. The receiver, Fig. 1681, is placed in the counting-room, or any other suitable place where the valves can be got at readily. The large pipe entering the bottom of the receiver is used where there is a natural head of water. The hose at the left is connected with a hose from a force-pump or steam fire-engine. The pipes at the top are mains leading to each room in the building—each numbered to correspond to the number of the room to which it leads—and cut off from the receiver by valves. The mains are water-tight until they enter the rooms, where the perforated pipes or "sprinklers" begin. The latter cross the rooms at intervals of 8 or 10 feet. If, for example, a fire occurs in any room—say room No. 3—the valve of No. 3 leading-pipe is turned, and in an instant a fine rain-shower of spray fills that room. As soon as the fire is extinguished, the valve, upon being turned back, will immediately stop the supply of water; and as soon as the pressure is turned from the receiver, the valve is again opened, and the water remaining in the pipes escapes from a waste-cock at the bottom. (See also ENGINES, FIRE.)

FISH-PLATE. See RAILROAD.

FLASK. See CASTING, and PATTERN-MAKING AND MOULDING.

FLAX, MACHINERY FOR PREPARING AND SPINNING. To prepare flax for manufacture, the stalks with the roots are pulled and set up in bundles to dry. The seed is then removed by rollers which act upon the bolls. The retting process follows. This consists in steeping the stalks in partially stagnant water for about three weeks, during which time fermentation takes place. The flax fibre being the bark or rind of the flax plant, of which the interior or core is a semi-wooden substance called *boon*, the object of retting is partially to decompose this woody substance so that it becomes brittle when dry; and the fermentation should not be continued so long as to injure the strength of the fibre, but long enough to loosen the gum which causes the bark to adhere to the woody portion. When thoroughly dried, the flax is ready to be broken. This is done in the *breaking* machine, which has fluted or grooved rollers, between which the flax-stem is made to pass, so that the woody fibre becomes well broken without being cut. Next comes the *scutching* machine, in which revolving blades or arms beat out the woody fragments, and the fibres are to a certain degree separated. In some processes the flax is now directly hackled; but since the introduction of the principle of spinning flax wet, various methods have been adopted to render the fibre finer, or in other words to split it up into a greater number of fibres, by the hackling operation. In order to obtain the finest fibre, it was found necessary to break or cut the flax into three lengths, and this is done in a cutting machine which contains a circular saw about 20 inches in diameter, constructed of three or four plates of steel, each about a quarter of an inch thick, and armed with angular teeth projecting from their circumference. This circular saw revolves with considerable velocity. A boy, grasping a handful of flax firmly at both ends, passes it between two pairs of grooved pulleys, which revolve slowly on either side and carry it against the saw, which tears off first the root end and then the top of the stem from the middle. The flax is thus divided into three lengths: the coarse and strong root-ends, the fine and strong middle, and the still finer but less strong tops. These lengths are collected into separate heaps, "stricks," or "locks," of which there are 300 or 400 to the cut.

HACKLING.—Flax may be either hand-hackled or machine-hackled. The operation of hand-hackling requires much experience in order to attain dexterity. The first tool used by the workman is the *ruffer*, which is a rude kind of comb, consisting of a tin-covered stock of wood three-quarters of an inch thick, studded with iron or steel teeth. Each tooth is about a quarter of an inch square at the base and 7 inches long, tapering to a fine point. The stock is screwed to a board a little broader and some inches longer than itself, which again is fixed to the bench slantwise. The points of the teeth incline from the hackler, and a sloping board at a still greater inclination is placed behind the teeth, to prevent the flax from entering them too far. The hackler grasps one of the handfuls of flax by the middle, spread out as flatly as possible, between the forefinger and thumb, and, winding the top end about his right hand to prevent it from slipping, he proceeds by a circular sweep of his hand to lash the root end of the flax into the teeth of the ruffer, commencing as near the extremity as possible, and gradually working up to his right hand, collecting now and then the fibres by holding his left hand in front of the ruffer and turning the flax from time to time. When the hackler has ruffed the root end, he seizes the flax by the part that has been ruffed, and proceeds in a similar manner to ruff the top end. As it is impossible to ruff entirely up to the hand, there must of necessity be a certain space left to be subsequently passed through the ruffer; this is called the "shift"; but the less length that is required for this purpose the better. The next tool used by the workman is the "common eight," which is similar in form to the ruffer, except that the pins are much closer placed and are not more than 5 inches long. The flax is not wound round the hand, but is laid upon the back board with the left hand, over the points of the pins, a slight lowering of the right hand and the angle of inclination of the instrument causing it to enter the pins sufficiently on being drawn forward. From the "common eight" the flax can be taken to other tools, called the "fine eight," the "ten," the "twelve," and the "eighteen," to be still further hackled. The object of this process is to split the filaments of the flax into their finest fibres arranged in parallel order, and, so to speak, combed. The flax is divided by this process into two kinds of fibre, called the "line" and the "tow." The longer fibres (or "line") remain in the hand of the hackler as he proceeds; the shorter fibres (or "tow") adhere to the teeth of the instrument, and require to be removed from time to time. In the hands of an unskillful operative the best flax will all be converted into tow. A good hackler feels at once the degree of resistance, and draws the flax with suitable force and velocity, and throws it more or less deeply among the teeth, according to circumstances. It was thought at one time that the requisite delicacy of manipulation could only be secured by manual dexterity; and even

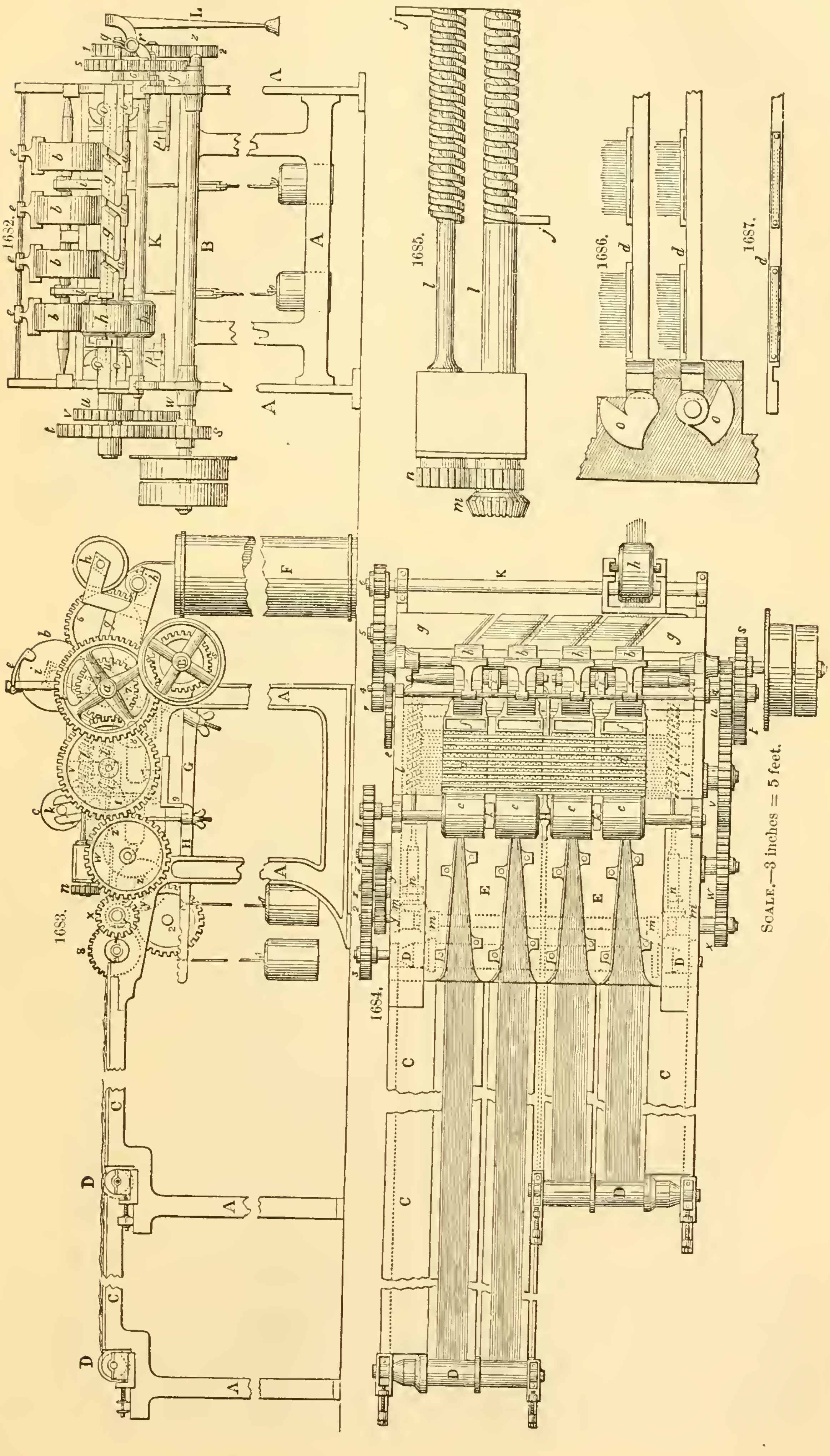
after the introduction of machine-spinning, hand-hackling was solely employed. The progress of invention has, however, in recent years enabled the spinner to substitute, to a very large extent, machines for hand-hackling. The flax, divided as previously mentioned into stricks, is spread out and placed between a pair of short iron bars, which are screwed together and hold it firmly, like the hand of the hackler. Each pair is called a "holder," the screws of which are 4½ inches apart. A number of these holders are fixed to a cylinder at distances a few inches apart. The root ends of the flax fall upon an inner cylinder covered with sharp teeth, which revolves slightly and hackles the flax, while the outer cylinder revolves slowly in the opposite direction. When the holders have passed through about half a circle, they are deposited by the outer cylinder upon a kind of rail. The machine-minder, generally a girl, then removes them to another machine similar to the first, where the uncombed ends fall upon an inner cylinder, and are hackled like the ends previously combed. Sometimes the entire process is performed by one machine, the holders being opened by the machine-minder, after the root ends have been hackled, and the flax turned the other way. To cleanse the points of the hackling teeth from tow, a series of brushes, fixed upon wooden cylinders, are provided; these brushes pass between the points and remove the tow. One of the best hackling machines is Ardell's intersector, in which two hackling cylinders operate upon the strick of flax, and hackle it on both sides at the same time. Combe & Co., of Belfast, manufacture a self-acting sheet machine, very suitable for hackling the coarser kinds of flax. The hackles are placed upon a flat surface or "sheet," as the cylinder is not well adapted for hackling large uncut flax. The nature of the operations in the "circular" and "flat" machines is the same, except that in the circular the flax is acted on by hackles fixed on the circumference of a cylinder, and in the flat by hackles fixed on an endless sheet.

The appearance of the flax after hackling is much changed: the line consists of long, fine, soft, and glistening fibres of a bright silver-gray or yellowish color, and when seen from a short distance having very much the appearance of silk.

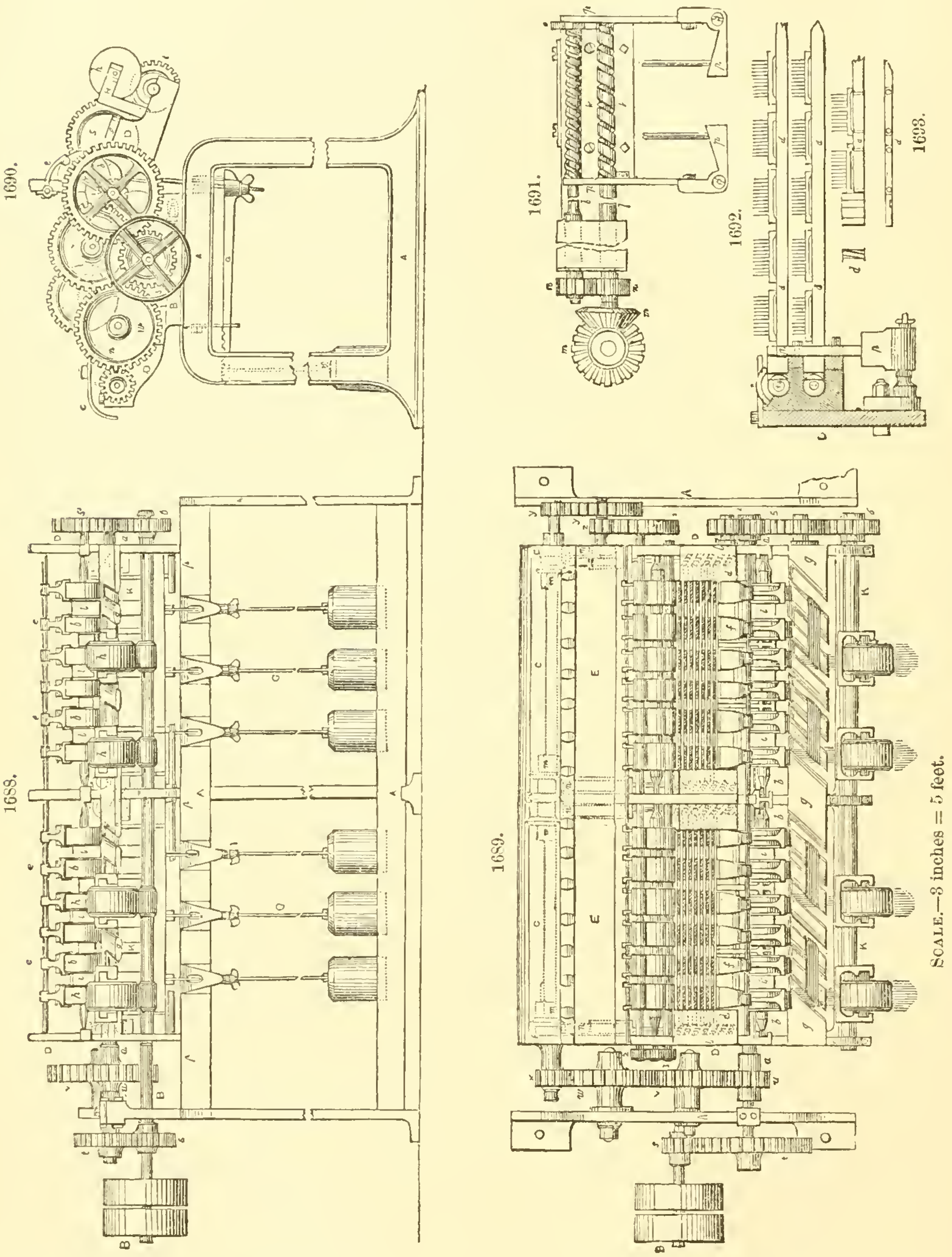
Sorting.—The next operation is called *sorting.* The hackled flax is taken to the sorting room, where the stacks are separated into various divisions, according to the degrees of fineness. Before the line-sorter is placed a kind of table, containing a number of boxes for receiving the various qualities of line. These boxes are respectively labeled 2 lb., 3 lb., 3½ lb., 4 lb., 5 lb., 5¾ lb., 6½ lb., etc., from an old system of comparing fineness with weight. He judges of the various degrees of fineness by the touch, as well as by the eye. A block hackle stands on the table, through which he frequently draws the line, to keep the fibres parallel.

Spreading and Drawing.—Each of the stricks of flax is subdivided into two or three portions, which are arranged longitudinally on the creeping-sheet (or feeding-cloth) of a spreading machine, the ends of the successive portions overlapping each other about three-fourths of their length. The construction of a spreading machine which produces the *sliver* or foundation of the future yarn is shown in Figs. 1682 to 1687. Fig. 1682 is a front elevation of the spreading machine; Fig. 1683 a side elevation; Fig. 1684 a general plan; and Figs. 1685, 1686, and 1687 detached views, on an enlarged scale, of the spirals and fallers. *A A A*, the cast-iron framework of the machine. *B B*, the driving shaft, fitted with a fast and loose pulley. *C C*, the feeding or *spreading* table; it is divided into two compartments, the one being considerably longer than the other, for the convenience of the attendants who spread the flax. *D D D*, rollers situated at each end of the feeding-table; over these pass four endless leather straps, upon which the stricks of flax are spread. *E E*, a polished iron plate, upon which are fixed the guides which serve to conduct the flax to the back or detaining rollers. *F*, a cylindrical tin can, placed in front of the machine to receive the sliver. *a a a*, the front or lower *drawing roller.* *b b b*, the top drawing or *pressing* rollers, made either of wood or iron, and covered with leather. *c c c*, the back or *detaining* rollers. *G G*, two weighted levers for imparting the requisite pressure to the top drawing rollers. *H H*, two weighted levers bearing in a similar manner upon the top detaining roller. *d d*, the *fallers* or *gill-bars*, forming a sheet of advancing hackles between the detaining and drawing rollers; these are for the purpose of producing great regularity in the draught, and a perfectly parallel distribution of the fibres. *e e e*, the *rubbers* for clearing the top drawing rollers from adhering fibres. *f f f*, brass guides for conducting the sliver to the drawing rollers. *g g*, the *sliver-plate*, formed with beveled openings for the sliver to pass through toward *h h*, the *calender rollers*, by which the four slivers are compressed into one, and delivered in the form of a ribbon into the can *F*. *K*, the calender rolling shaft. *i i*, cast-iron hangers for transmitting the pressure of the weighted lever *G* to the top drawing rollers. *k k* are similar hangers attached to the lever *H*. *l l*, the spirals or screws, into the spaces between the threads of which the ends of the fallers are inserted. *m m*, two pairs of small bevel-wheels by which the lower spirals are driven from the *back shaft.* *n n*, two small spur-wheels communicating motion from the lower to the upper spirals. *o o*, the tappets or *cams* by which the fallers are elevated in succession from the lower to the upper spirals, and *vice versa.* *p p*, small weighted levers for guiding the fallers between the threads of the spirals. *q*, a small endless screw cut upon the extremity of the axis of the lower drawing rollers *a a*; it works into *r*, a worm-wheel on the axis of which is another endless screw, driving a similar wheel, called the *bell-wheel;* at every revolution of this last wheel, a pin fixed into its rim acts upon a spring *L*, to the end of which a bell is attached, the ringing of which serves to register the length of the sliver delivered into the can.

The following is the detail of the wheel-work in this machine: On the driving-shaft *B* is fixed the spur-pinion *s*, working into the wheel *t* on the lower drawing-roller shaft; to this latter axis is affixed the wheel *u*, whose motion is communicated by the movable intermediates *v* and *w* to the change-pinion *x* on the back shaft; the relative diameters of these wheels regulating the amount of draught or the degree of extension which the flax sustains in passing between the detaining and drawing rollers. The opposite end of the back shaft carries the pinion *y* working into the stud-wheel *y'*, having on its boss the pinion *z*, which, by means of a movable intermediate *z'*, drives the wheel 1' on the


1682.
1683.
1684.
1685.
1686.
1687.
SCALE.—3 inches = 5 feet.

axis of the detaining roller. This train of wheel-work is calculated to produce a nearly uniform surface speed of the rollers and the sheet of hackles. A slow motion is communicated to the *sheet roller D*, over which the feeding-bands pass, by means of the spur-wheel 3 working through an intermediate 2 into the pinion *z*. A uniform velocity is imparted to the lower drawing- and calender-roller shafts *a* and *K*, by a pinion 4 on the extremity of the former, working through an intermediate wheel 5 into a similar pinion 6 on the end of the latter. And lastly, a revolving brush situated under the lower range of fallers, for the purpose of clearing away the dust, is driven by the stud-



1690. 1691. 1692. 1693.

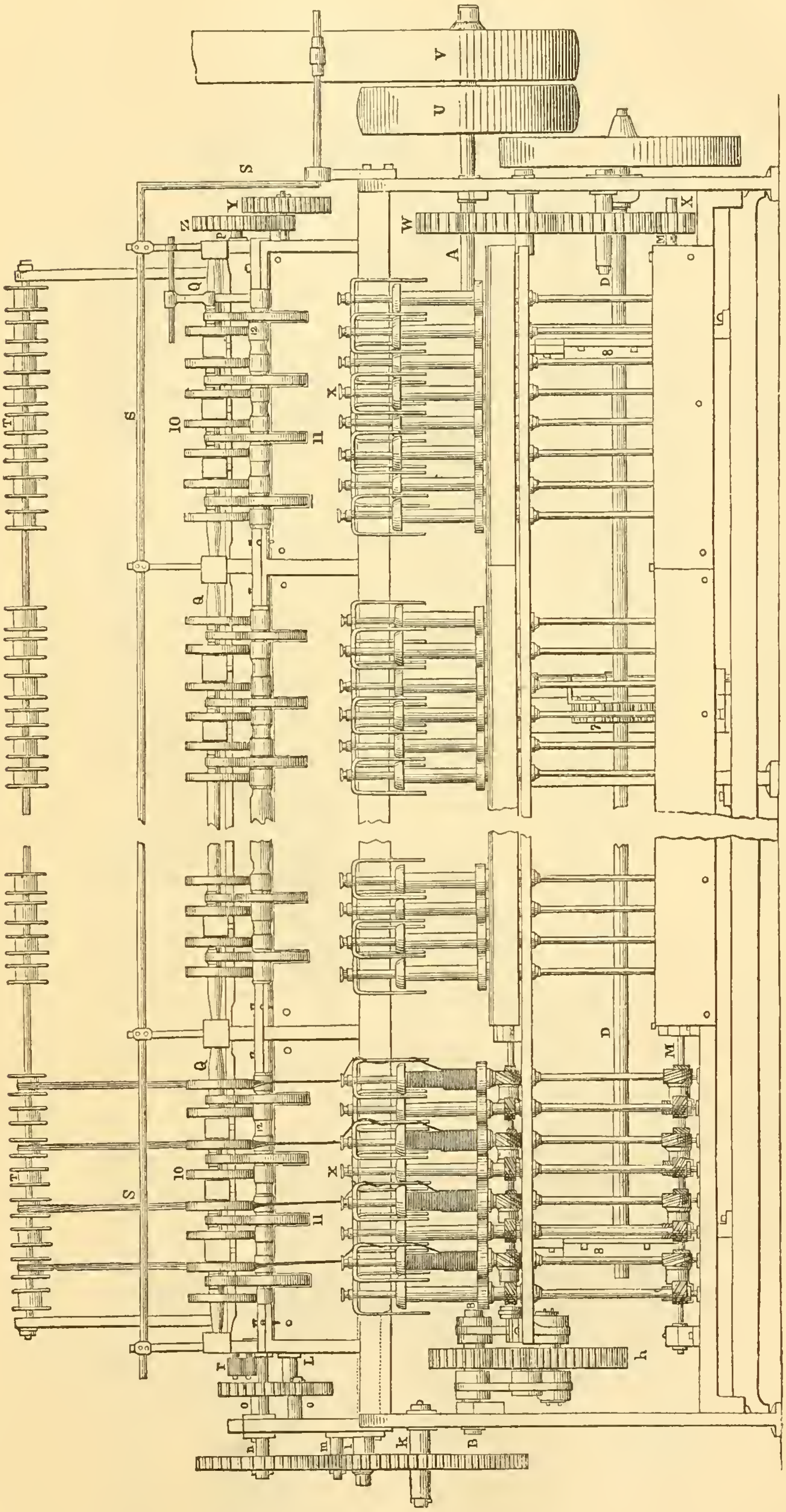
1688. 1689.

SCALE.—3 inches = 5 feet.

wheel 7, gearing with the pinion 4, and having on its boss a small pinion working into the wheel 8 on the end of the brush-shaft.

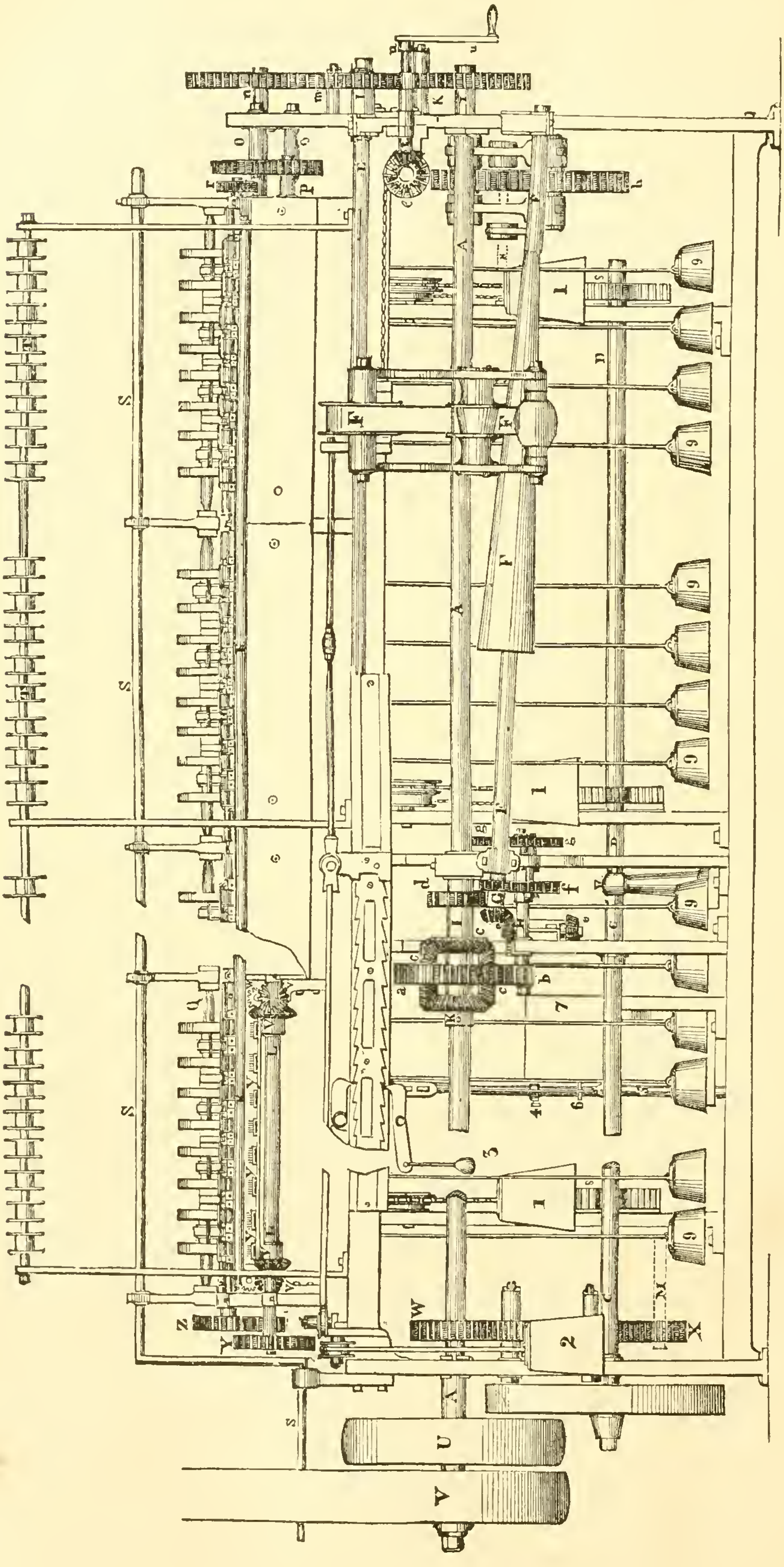
*Action of the Machine.*—The flax is placed in the sheet-iron guides behind the detaining rollers and along the endless bands or feed-sheets, by laying down one handful after another, so that the points of the second strick reach to about the middle of the first, and thus preserve a uniformity of thickness in the feeding. By the motion of the machine it is introduced between the back rollers *c c*, and carried forward by the sheet of hackles *d d* toward the front or drawing rollers *a a b b*, which, revolving at a velocity considerably greater than the former, lengthen or draw it out to a proportional extent; the hackles at the same time combing, separating, and straightening the fibres. The

1694.



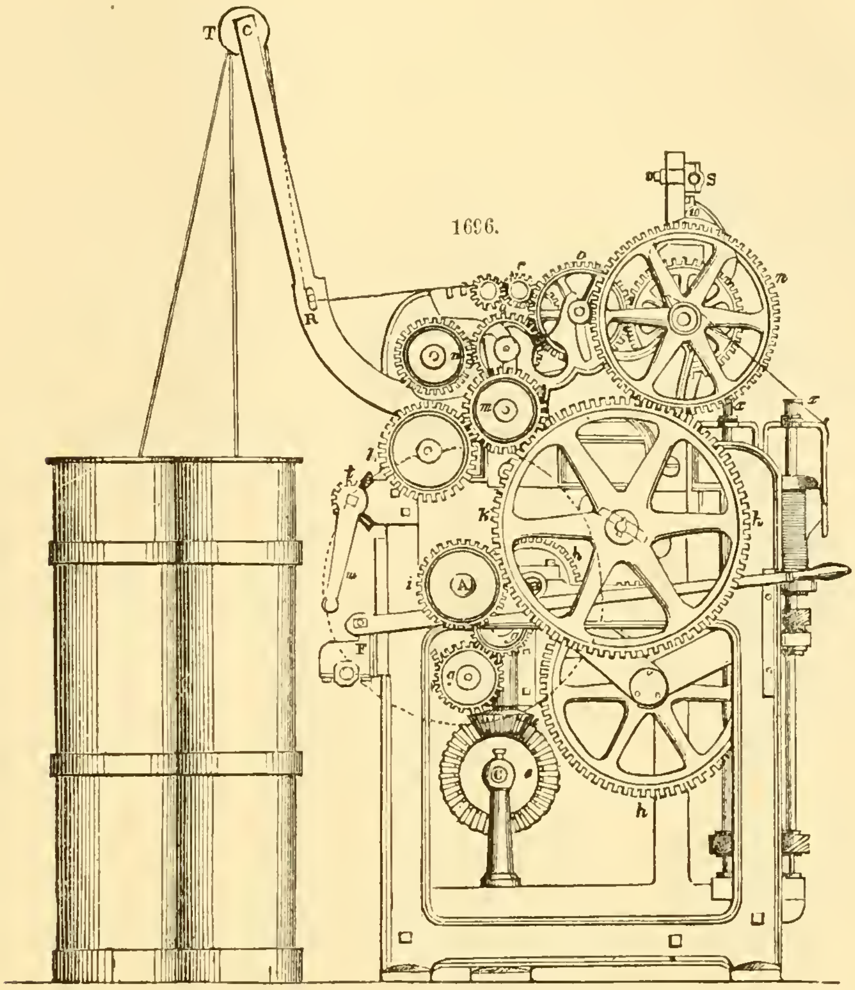
SCALE.—3 inches = 4 feet.

1695.

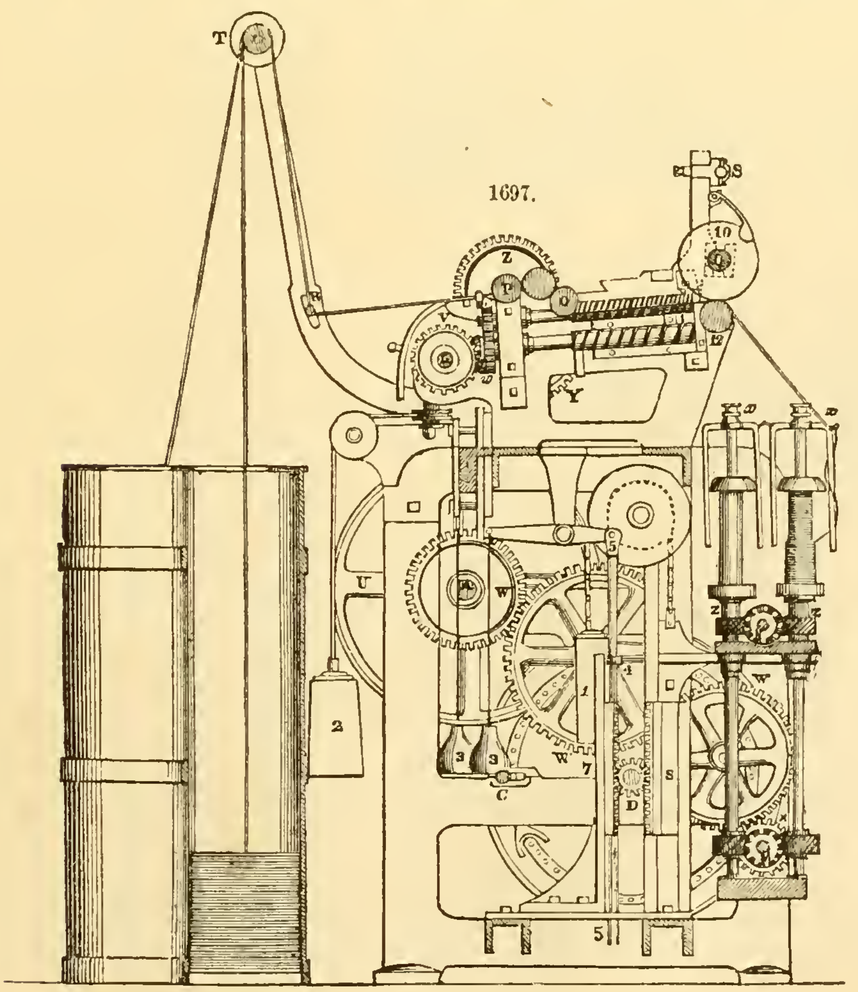


SCALE.—3 inches = 4 feet.

1696.



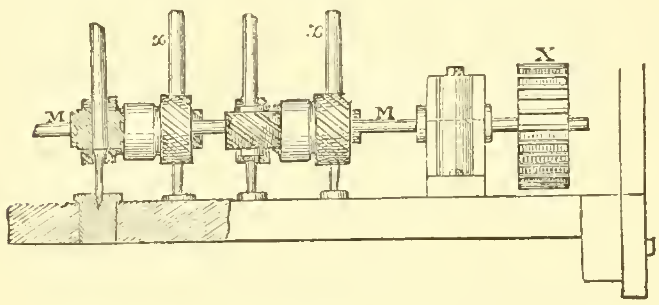
1697.



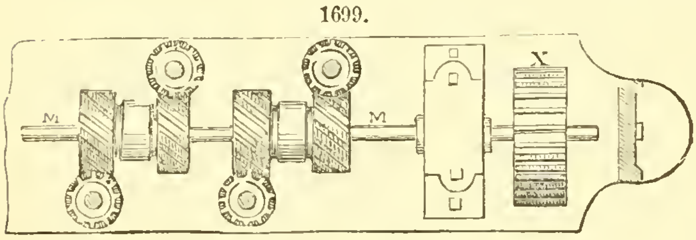
slivers from the four drawing rollers are then passed through the bevel-slits in the sliver-plate *g g*, and united into one by the calender rollers *h h*, where they are subjected to a gentle pressure and delivered into the can *F*. This union of the slivers is necessary in order that the varying thickness of each may be compensated and perfect uniformity attained. When the can has received its destined supply, the ringing of the bell warns the attendant to break the flax, remove the can, and substitute another.

*The Drawing-Frame.*—The next process in the preparation of flax consists in causing it to pass twice in succession through the drawing machine, for the purpose of still further increasing the fineness and uniformity of the sliver. These machines, which are represented in Figs. 1688, 1689, and 1690, are in principle identical with, and in the details of their construction very similar to, the spreading machine already described. They contain, as will be seen by the drawings, two sets of fallers and rollers, and the place of the feeding-table and guides is supplied by a bent plate of polished sheet-iron *C*, extending across the entire breadth of the machine, over which the slivers glide in passing from the cans to the detaining rollers. These latter differ slightly from those used for the same purpose in the spreading machine; here they are three in number, and coupled together by small pinions, 1, 2, and 3, and disposed in a triangular form, the sliver being made to pass under the first, over the second, and under the third. With these exceptions there is no essential difference between the present machine and that last described; and as the same or analogous parts are designated in both by the same letters, it will be unnecessary to repeat the description.

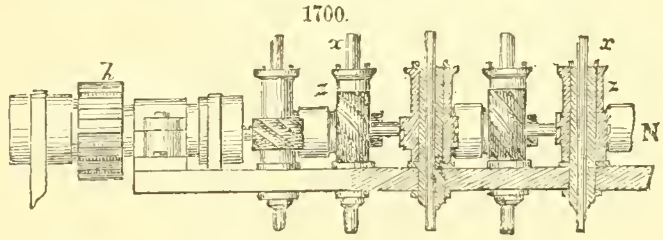
1698.



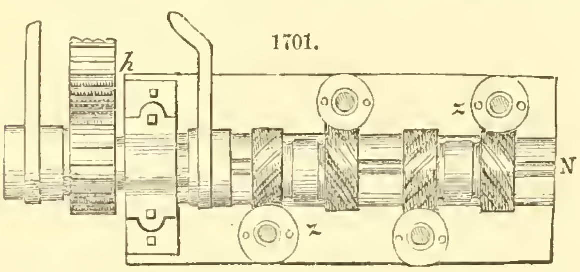

1699.




1700.




1701.

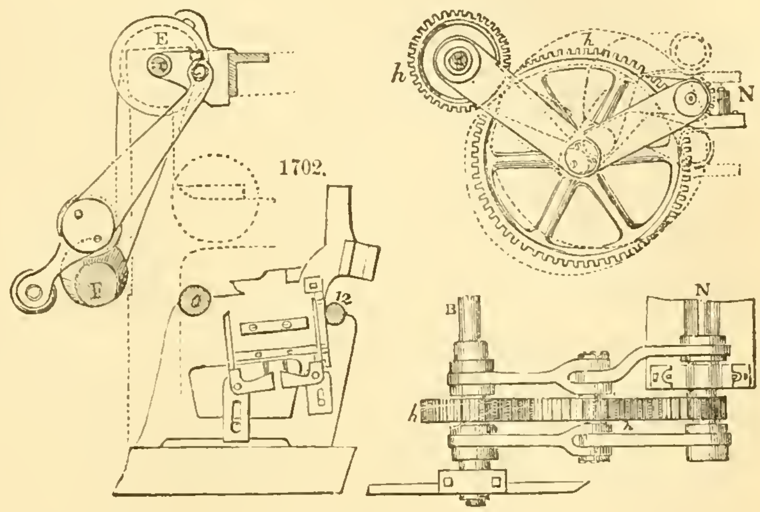



*Spiral or Screw Gill.*—Figs. 1691, 1692, and 1693 give a representation of a very interesting and important piece of mechanism which enters largely into the construction of modern flax machinery. This ingenious contrivance has in a great measure superseded all former modes of effecting the same object, which is combing and separating the fibres of the flax, in order to facilitate the drawing and to give uniformity to the sliver. The fallers or hackle-bars *d d*, Fig. 1692, are supported at both extremities by the horizontal steel guide-rails *k k*, screwed to the insides of the sockets in which the spirals or screws *l l* work; these sockets being bored in projecting parts cast upon the stands *D D*. The lower screw is driven from the back shaft by a bevel-wheel and pinion *m m'*, and a small spur-wheel *n*, on the back of the bevel-pinion, works into a corresponding wheel on the top screw, driving both screws at equal velocities but in contrary directions. In the sides of the sockets in which the screws revolve, openings are formed, parallel with their axes and coinciding with the surfaces of the guide-rails *k k*; through these openings the ends of the gill-bars (which are steeled and beveled to compensate for the angle of the threads) are inserted into the helical grooves of the screws. Thus the rotary motions given to the spirals cause the fallers to be driven along the guide-rails in a vertical position, and with a uniform simultaneous movement; the top sheet in the direction of the drawing rollers, and the lower toward the detaining rollers. On reaching the front part of the machine, close behind the drawing rollers, the fallers are depressed and put out of operation by means of the rotary cams *o o*, fixed to the ends of the top screws; being guided vertically downward between the ends of the upper guide-rails and the weighted levers *p p*. They are thus engaged in the threads of the lower screws, which carry them to the opposite end, where similar cams *o o*, and weighted levers *p p*, raise them successively into their original position on the upper guide-rails, where they are traversed forward as at first. It is usual to make the lower spiral with the threads considerably wider than those of the upper, which arrangement diminishes the total number of fallers requisite for the due performance of the work.

*Self-regulating Spiral Roving Machine.*—Fig. 1694 presents a general elevation of the entire machine as seen in front; one of the plates which protect the spiral pinions being removed in order to show the mode of giving motion to the spindles, fliers, and bobbins. Fig. 1695 is a corresponding general elevation of the back of the roving frame, exhibiting the cone and differential movements, and, by the removal of one of the covering plates, exposing a part of the back shaft and gearing

for working the fallers. Fig. 1696 is an end elevation, showing the principal gearing employed in this machine. Fig. 1698 is an elevation, partially sectioned, of a portion of the spindle rail or beam, and Fig. 1699 is a plan corresponding. Fig. 1700 is an elevation, also partially sectioned, of part of the bobbin-lifter, with its attached gearing; and Fig. 1701 is a plan of the same. Fig. 1697 is a transverse section of the machine, exhibiting some of its internal arrangements, and showing the course of the sliver from the cams to the bobbins. Fig. 1702 is an elevation of part of one of the stands, showing the slides, springs, and weighted levers used for defining the course of the fallers. Fig. 1703, an elevation and plan of the contrivance for transmitting motion to the axis of the spirals on the bobbin-rail. Fig. 1704, a cross section of a part of the machine, showing the apparatus for maintaining constant tension upon the strap driving the cone-pulley of the traverse and equational bobbin motions.

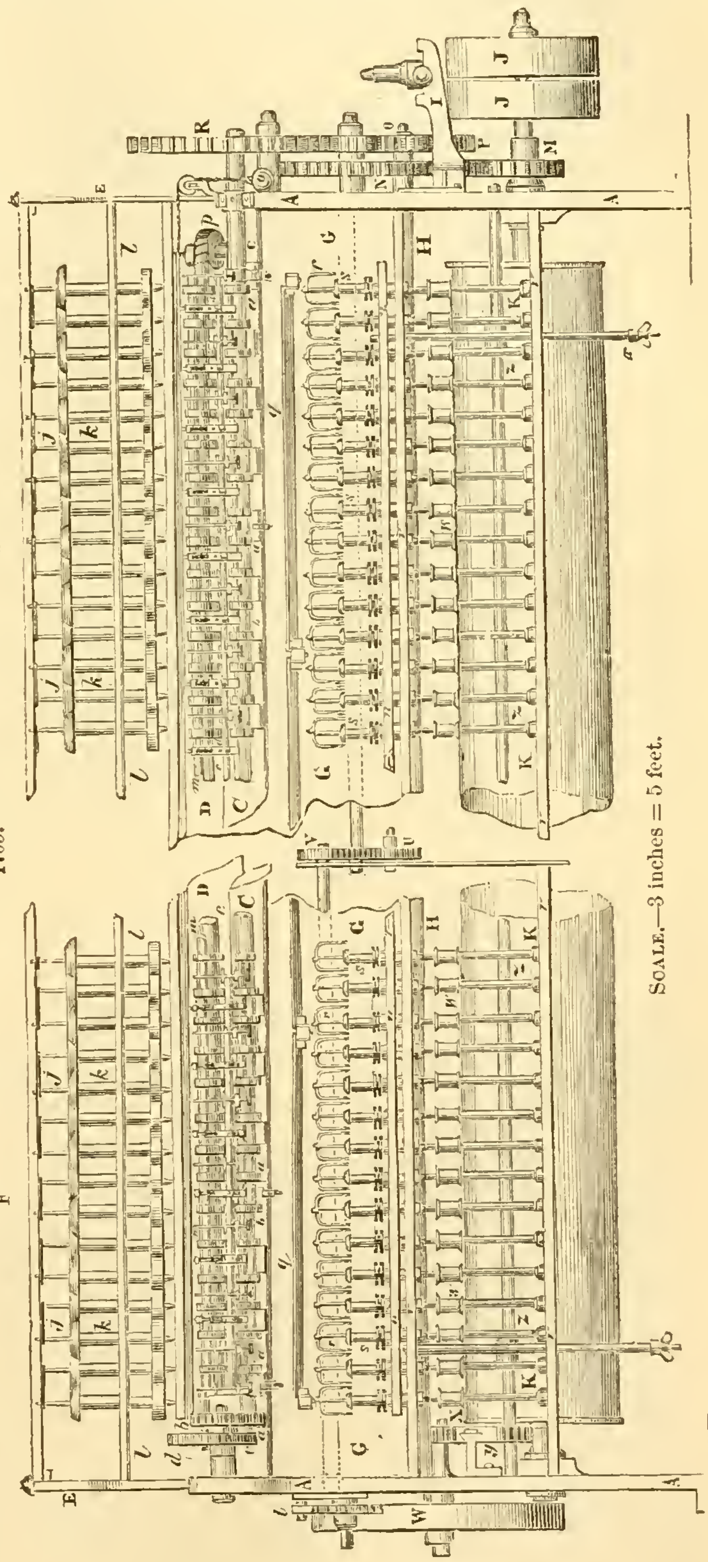
1704. 1703. 1702.



*A A*, the driving-shaft, situated toward the back of the machine and extending throughout its entire length. *B B*, a shaft parallel and near to the driving-shaft, extending from the centre to one end of the machine. It carries a spur-wheel at each extremity, one of which is commanded by the equational bobbin motion, while the other, by means of a peculiar arrangement of gearing, to be hereafter described, transmits the motion to the spiral shaft on the bobbin-rail. *C C*, the mangle-pinion shaft, worked by a train of bevel-wheels from the cone shaft, and, through the mangle-wheel, situated at one end of the machine, close to the driving pulleys, working. *D D*, the mangle-wheel shaft, extending the whole length of the machine, and carrying pinions working into racks 8, 8, 8, attached to vertical slides; these slides are furnished with projecting arms fixed to the bobbin-rail, which is traversed up and down by the mangle-wheel, causing the fliers to wind the roving between the flanges of the bobbins with all the regularity of a screw. Counterbalance weights 1, 1, 1, attached to the bobbin-lifter by means of chains passing over pulleys, serve to relieve the racks from all unnecessary strain. *E*, a short shaft situated at the back of the machine, and driven by a train of spur-wheels from the driving-shaft at the same velocity as the latter. Upon this shaft is suspended a species of frame, fitted to slide longitudinally upon it, and carrying two pulleys and a weight at the extremity; the first pulley being adapted to rotate with the shaft *E* by means of a long slot and sunk feather, and the other being merely a conical friction-roller, for the purpose of maintaining a constant tension upon the strap driving the cone *F*, Fig. 1704. The frame, with its appendages, is traversed along the shaft by means of a weight 2, situated at the opposite end of the machine, and attached by a chain and adjustable rod to the frame and to a rack working in a slide fixed to the back of the roller-beam, Fig. 1697. This rack is serrated on both edges, the teeth of the upper alternating with those on the lower edge, and the pawls are alternately disengaged at every revolution of the mangle-wheel in such a manner as to allow the drag-weight to advance the rack and pulley frame by half the distance between two contiguous teeth. The mechanism by which the pawls are disengaged is as follows: At the back of the rack-slide a short rectangular bar is fitted to slide vertically, having two projecting pins acting upon the points of the clicks, Fig. 1697. This bar is worked by the end of a lever inserted through its lower extremity, and having its fulcrum under the roller-beam; to the other end is attached the vertical rod 5, carrying two adjustable catches 4, 4, which at every alternate movement of the mangle-wheel are struck by an arm 6 extending from the rack 7. Thus one of the pawls is constantly in gear to prevent the rack and attached pulley frame from being drawn beyond the prescribed limits for each stroke. The lower pawl is kept pressed against the rack by a counterweight 3. while the upper one merely rests on it by its own gravity. The pitch of the teeth on the rack must be varied according to the degree of fineness of the roving. *F*, the cone driven by a strap belt from the pulley on the shaft *E*, and communicating a gradually retarding motion at once to the bobbins themselves and to the traverse of the bobbin-rail, the velocity of the spindles and fliers remaining constant. This is necessary in order to compensate for the continually increasing diameter of the bobbins as the roving is wound upon them. The cone is set at a slight inclination, in order to allow the belt to act upon a greater part of its periphery toward the apex than toward the base, where, on account of the increased diameter, this precaution is less necessary to insure the rotation of its shaft. A lever handle (seen in the end elevation, Fig. 1696) is attached to the carriage of the cone-shaft, for the purpose of raising its outer extremity previously to winding back the pulley-frame. *G H*, two short shafts situated toward the centre of the machine, and carrying gearing, to be hereafter specified, for transmitting the motion of the cone-shaft *F* to the traverse and equational bobbin motions respectively. *I*, a hollow boss fitted to rotate upon the driving-shaft *A*, with a motion independent of that of the latter, and carrying at one end a spur-pinion working into a wheel on the shaft *B*, and at the other a bevel-wheel, being part of the equational bobbin motion. *K* is a similar bevel-wheel fast upon the driving-shaft *A*. *L L*, the back shaft, traversing the entire length of the machine, and carry-

ing the bevel-wheels for working the mechanism of the fallers. *M M*, a longitudinal shaft working in bearings on the spindle-rail, and carrying the spiral pinions for conveying motion to the spindles and fliers, Figs. 1697, 1698, and 1699. The spindles are disposed in two rows, so that each spindle in the back range stands opposite to the interval between two in the front range. The object of this distribution is economy of space, as the machines would require to be greatly longer if the spindles stood all in one line. The shaft *M* is situated between the two rows, and drives both rows in the same direction. *N N*, a longitudinal shaft working in bearings on the bobbin-rail, and carrying the spiral pinions for working the bobbins, Figs. 1697, 1700, and 1701. The spindles pass through brass sockets fixed to the bobbin-rail to hold them steady as the latter traverses up and down. These sockets serve also as pivots for the spiral pinions to revolve upon; it being understood that the motion of the bobbin spirals is totally independent of that of the spindles. A small flange on the top of each spiral carries two projecting pins fitting into corresponding holes in the bottom of the bobbins, and causing both to revolve together. *O P*, the back detaining rollers, having the iron pressing rollers between them, which are cut into short lengths, and are carried round by the friction caused by their own gravity. *Q Q*, the axes of the pressing or top drawing rollers marked 10, which are usually made of wood, and are pressed against the lower drawing rollers 12, 12, by hangers 11, 11, resting in necks cut in the axes and attached to weighted levers 9, 9, passing under the roller-beam. *R R*, a slender rod extending the entire length of the machine, for conducting the slivers to the detaining rollers. They pass under this rod, and slide over a polished sheet-iron plate covering the back shaft and bevel-gearing for driving the gill-screws. *S S*, a rod by which the attendant is enabled at any part of the machine to stop or set it in motion. *T T* are a set of friction-pulleys placed upon a rod surmounting the machine, for the purpose of guiding the slivers as they are drawn out of the cans by the action of the machine. *U V*, the fast and loose pulleys on the end of the driving shaft for starting and stopping the machine. *W W W* is a train of spur-wheels conveying the motion of the driving-shaft *A* to *X*, a spur-pinion on the end of the shaft *M*, which drives the spindles and fliers with a uniform motion. *Y Z*, the draught-gearing between the drawing and detaining rollers, the particulars of which will be given below. *a b*, *c c*, and *d* are spur and bevel wheels and pinions, the combination of which forms the differential motion for driving the bobbins. Supposing that the large spur-wheel *a*, which, through the pinion *b*, receives its motion from the cone, were driven at the same velocity as the driving-shaft *A*, then it is obvious that no motion whatever would be imparted to the bobbins. On the other hand, if the wheel *a* were held absolutely immovable, the bevel *K*, which is fixed upon the driving-shaft, would convey, through the pinions *c c*, a motion equal to its own, though in the contrary direction, to the boss *I* and attached gearing; consequently, in the case we have last supposed, the motion communicated to the bobbins would be uniform. Hence, by combining the two extreme cases, and supposing the wheel *a* to be driven in the direction of the driving-shaft, but with a slower velocity, it will be understood that the boss *I* will be made to revolve at a speed which, if added to that of the wheel *a*, will be exactly equal to that of the driving-shaft *A*. Thus, when the driving-strap is at the apex or starting-point of the cone *F*, the wheel *a* is at its maximum velocity, and the boss *I* with the train of wheels to the bobbins at their minimum, causing the fliers, which revolve at a considerably greater *uniform* speed, to coil the given quantity of rove upon the bobbins; then as the strap advances toward the base of the cone (every point in this advance being simultaneous with the commencement of a fresh layer of roving), the speed of the wheel *a* is diminished, causing that of the boss *I* to *increase* in the same ratio, and thus approximating the speed of the bobbins to that of the fliers, at every alternate motion of the traverse. In this way the irregularity due to the varying diameters of the bobbins is compensated, and a uniform very slight tension maintained upon the slivers between the fliers and the drawing rollers. *e e c*, a train of bevel-wheels and pinions for conveying the motion of the short shaft *G* to the mangle-pinion shaft *C*. *f g g*, a train of spur-wheels and pinions (including change pinions) for conveying the motion of the cone *F* at once to the traverse and equational motions. It is obvious that to preserve the regularity of the winding, the speed of the traverse or copping motion, as well as that of the bobbins themselves, must be progressively retarded. *h h h*, a train of spur-wheels for conveying the differential motion to the bobbin-shaft *N*. The pinion *d* on the boss *I* works into a wheel fixed to the end of the shaft *B*; this shaft has another spur-wheel *h*, Figs. 1696 and 1703, upon its opposite extremity, which gears with *h*, an intermediate wheel suspended in a joint formed by the meeting of two pairs of arms, one of which have their centre of motion on the shaft *B*, and the other on the shaft *N*. Thus, when the latter ascends and descends in obedience to the traverse motion, the arms move in a radial direction round their respective centres, and consequently the suspended wheel *h* is kept constantly in gear both with the wheel on the end of the shaft *B* and with the pinion on the shaft *N*. This will be clearly understood by observing the dotted lines in Fig. 1703, which denote the different positions of the bobbin-lifter, and the corresponding positions of the arms and intermediate wheel. *i k l m*, a train of spur-wheels for conveying the motion of the driving-shaft to the shaft *E* working the cone motion, Fig. 1696. *n* is a spur-wheel on the end of the drawing roller, also working into the movable intermediate *k*, which thus commands the drawing, bobbin, and traverse motions. The train *i k n* is called the *twist-gearing*, and its object is to vary the speed of the front roller while the speed of the spindles remains the same, and thus to put more or less twist into the rove as may be required. *o o p*, a train of wheels between the drawing rollers and the back shaft—*p* being a change pinion; these, together with the train *Y Z*, at the opposite end of the machine, constitute the draught-gearing. *r r*, small pinions connecting the detaining rollers together. *t u*, a handle and small bevel-wheels working a barrel round which is coiled a chain attached to the pulley-frame for winding the rack, etc., toward the apex of the cone *F*. *v v*, *w w*, *y y*, the fallers and gearing for working them, as minutely detailed in a preceding description. *x x x*, the fliers fixed upon the top of the spindles for twisting, guiding, and winding the rove upon the bobbins.

SPINNING.—The preliminary processes through which the line passes after it is hackled and before it is spun are termed, collectively, *preparing*. The rove-bobbins are now taken to the spinning room. Spinning consists in drawing the roving down to the last degree of tenuity desired, and twisting them into hard cylindrical cords, which are called yarns. The spinning of flax does not differ essentially from the spinning of cotton on the "throstle" principle. Mule-spinning, which is so well suited for a weak material like fine cotton, is not suited for the strong fibre of flax. In hand-spinning, the housewife used to moisten the fibres with her saliva, to make them adhere to each other, and also to make them more pliable and easy to twist; and in imitation of this practice, the fibres were formerly wetted in cold water previous to being spun by machinery. For cold water, water heated to a temperature of 120° is now substituted. This has been found to be a great improvement: a given weight of flax can be spun to double the length that it formerly could, and the thread that is produced is finer, smoother, and more uniform in texture than formerly. The hot water is contained in a trough which runs the whole length of the spinning frame. A dewy spray is continually thrown off by the machinery, against which the attendants protect themselves by waterproof aprons. Probably line which, when spun dry, would produce only 20 leas of yarn, would when wetted yield 70 leas or more, and be proportionately more remunerative.



1705.

SCALE.—3 inches = 5 feet.

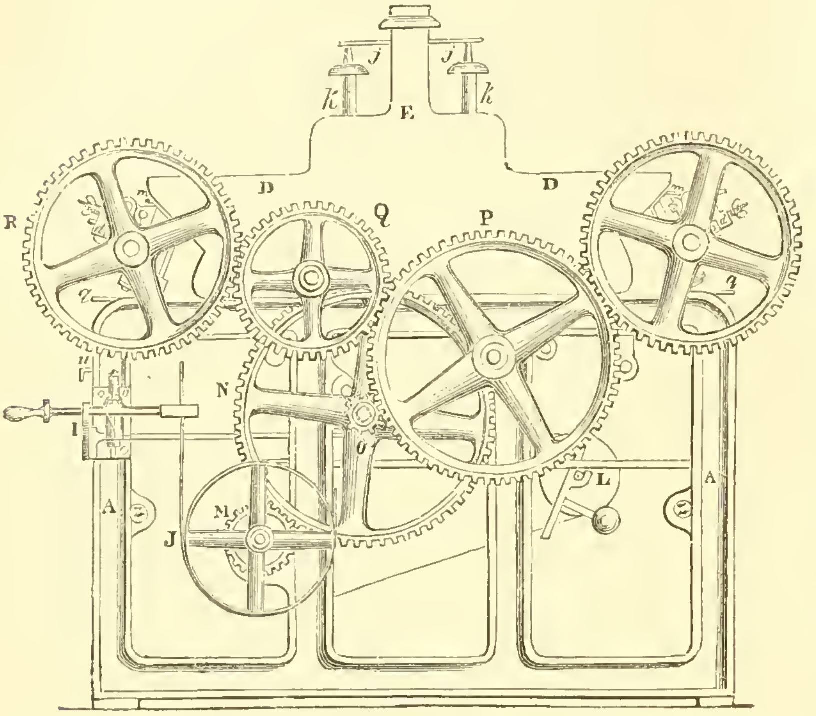
*The Wet Spinning Frame.*—With the exception of the hot-water trough and its adjuncts, this machine bears a close resemblance to the throstle frame of the cotton manufacture, and like it is employed for the completion of the yarn, after being subjected to the processes of drawing and roving. Although the principle of its operation is for the most part the same as that of the roving machine, it is much less complicated than the latter, inasmuch as it dispenses with the gill apparatus (which is, of course, only applicable to parallel slivers), and with the equational bobbin motion, which is rendered unnecessary by the circumstance of the yarn itself having attained a sufficient degree of cohesive force to enable it, with the aid of a simple contrivance, to regulate the drag upon the bobbins.

Fig. 1705 is a front elevation, broken in the middle, for the purpose of exposing part of the gearing for working the traverse motion; Fig. 1706 is an elevation of the gearing end of the machine; and Fig. 1707 is a transverse section of the entire machine.

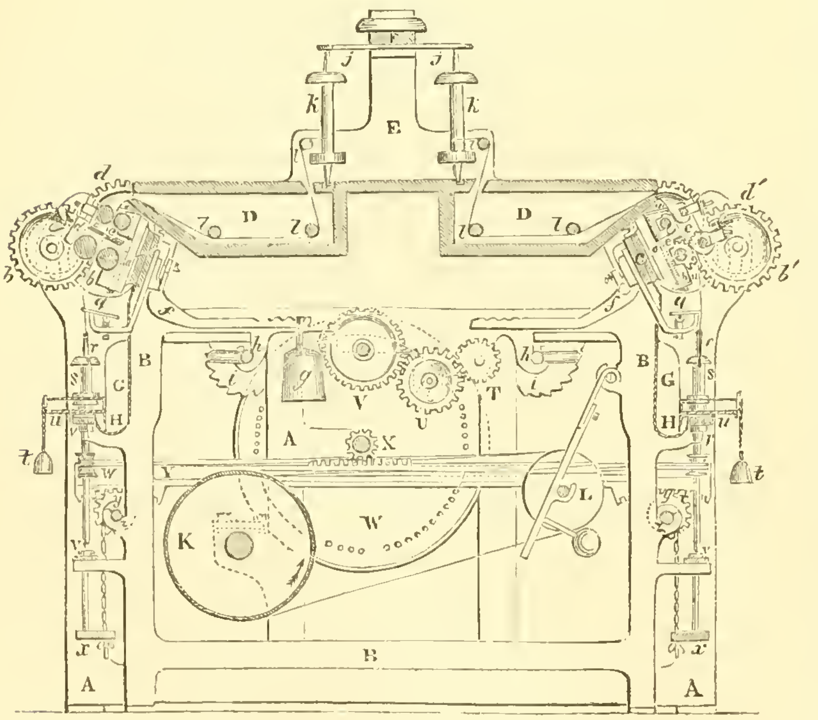
*Literal References.*—*A A*, the frame ends or standards of cast-iron. *B B*, the middle support. *C C*, longitudinal beams of cast-iron, on which are supported *a a*, the stands or framing of the rollers. The bottom or drawing-roller journals are fixed, while the top or detaining-roller journals slide on the upper part of the stands, and are regulated by screws (see dotted lines in Fig. 1707), so as to adapt the *reach* or distance between the drawing and detaining rollers to the various lengths of fibres. This distance should always be a little more than the average length of the filaments. *b b*, the bottom or drawing rollers, usually called the *front* rollers. *c c*, the top or detaining rollers, usually called the *back* rollers. Both front and back rollers are made of brass cast upon a wrought-iron shaft or axle, and fluted. *d d*, the *saddles* for retaining the pressing rollers in their proper places. The bushes or bearings of the top pressing rollers are made to slide upon projecting arms, in order

to suit the various lengths of reach. The top pressing rollers are generally made of brass and the bottom of boxwood, and both are fluted. *e e* are bolts fitted with adjusting thumb-screws for attaching the saddles *d d* to *f f g g*, levers with weights for giving the requisite pressure to the pressing rollers. *h h*, cranked axles extending the entire length of the machine for relieving the pressing rollers from the strain of the weighted levers when the machine is at rest. *i i*, ratchet-wheels fixed upon the end of the cranked axles for maintaining them in the position in which they may be placed. *D D*, the wooden troughs surmounting the machine, and through which the rovings pass before reaching the detaining rollers. These troughs are supplied with hot water, and kept at a high temperature by steam from a boiler. *E*, the *creel* in which the roving bobbins are placed vertically, in alternating rows. *F*, a wooden rail surmounting the creel, to which are attached *j j*, the slender sheet-iron supports for the top of the roving-bobbin spindles, the lower ends revolving in foot-steps on the top of the trough, Fig. 1707. *k k*, the bobbins, as filled with loose yarn by the roving machine. *l l l*, longitudinal brass rods for conducting the rovings into and through the troughs *D D*. *m m* is a flat brass rod, placed immediately above the detaining rollers, and extending the entire length of the machine; opposite to each boss of the detaining rollers an indentation is cut in the rod *m*, for the purpose of guiding the rovings. A small endless screw is cut on the end of the detaining-roller shaft, and gears with a worm-wheel *p*, Fig. 1705, which works on a stud fixed to the beam *C*, and has a small *heart-wheel* formed upon its upper surface. A small steel pin *n* is fixed to the end of the rod *m*, and is pressed against the heart by a drag-weight *o*, attached to it by a chain passing over a small pulley. As the roller revolves, it produces a slow motion of the heart, causing the rod *m m* to traverse nearly the whole length of the boss, and thereby preventing the roving from wearing the surface of the rollers unequally. *q q*, the thread-plates or guides, having small notches opposite to each bobbin through which the threads pass on their way from the drawing rollers to the eyes of the fliers. These plates are made in separate lengths as may be convenient, and are hinged in order to enable the bobbins to be inserted into or withdrawn from the spindles. *G G* are sheet-iron linings extending from the beam *C* to *H H*, spouts formed under and within the rows of bobbins. These linings and spouts serve to collect and withdraw the water which is thrown off by the centrifugal force of the bobbins. *r r*, the fliers for guiding and winding the yarn on *s s*, the bobbins, formed with a species of pulley on their lower flanges. In this machine the bobbins are not driven independently of the spindles, for a reason which we have specified in our introductory remarks. The natural tendency of the bobbins to wind on the yarn regularly is assisted by the following contrivance: *t t* are drag-weights, attached by pieces of string to loops on the back of the bobbin-lifter; these cords pass across to a plate with a serrated edge fixed to the front of the bobbin-lifter, and press against the grooves formed in the lower flanges of the bobbins. The friction thereby occa-

1706.




1707.



sioned, which may be varied by changing the length of leverage at which the weights act, gives the bobbin the requisite retardation for winding on the yarn. *u u*, the bobbin-beams or lifters supported by the traverse rods *x x*, which are attached to bosses upon the traverse shaft *z z*, by chains furnished with adjusting thumb-screws for adapting the bobbins to the height of the fliers. *v v* are the spindle rails or beams, in which are inserted the steps and collars for the spindles to run in. *w w*, the spindles themselves, with their driving wharves or pulleys fixed to them. *I* is a bracket upon which works the strap-guide for starting and stopping the machine. *J J*, the fast and loose pulley fitted to the end of *K K*, a long cylinder constructed of tin plates and extending the entire length of the machine, forming a continuous drum for driving the spindles. *L*, a balance-pulley round which the tape passes for driving the spindles, and which keeps it at the proper tension. The tape passes over the cylinder *K*, then over the balance-pulley *L*, and round two spindles on each side of the frame, thus causing one belt or tape to drive four spindles. Previously to the introduction of this method, each spindle was impelled by a separate tape. *M N O P Q R S*, a train of spur-gearing (*O* being a change-pinion), constituting the twist-gearing, and conveying motion from the driving-shaft to the front rollers on both sides of the frame. *T U V*, a train of spur-wheels situated at the middle of the frame, and constituting a part of the traverse-gearing. *T* is a pinion fast upon the end of the shaft, which carries the intermediate twist-wheel *P*, and which has a bearing in the middle support *B*. This wheel works through the intermediate *U* into *V* upon the mangle-pinion shaft. *W* is the mangle-wheel, situated at the opposite end of the frame to the twist-gearing, and actuated alternately in both directions by the mangle-pinion. *X*, a small spur-pinion fixed to the axis of the mangle-wheel, and working into a rack formed on the top edge of *Y*, a cast-iron horizontal bar working transversely in slides bolted to the inside of the end framing *A A*. Each extremity of this bar is formed into a radial rack; these work into the eccentric spur-wheel *y y*, fixed upon the traverse-shafts *z z*, imparting to the latter a *graduated* motion of rotation, which is communicated to the bobbin-lifter by the mechanism previously described, causing the flier to wind the yarn upon the bobbin in a slightly spherical form. *a′ b′ c′ d′*, a combination of wheels forming the draught-gearing, precisely similar to the draught-gearing in the other machines which have come under our notice.

*Reeling.*—The bobbins are conveyed from the throstle-frame to the reeling room, where the yarn is unwound from the bobbins and measured on reels, the lowest denomination being the "lea" or "cut." The standard lea contains 300 yards. The next higher denomination is the "hank." Each hank contains 10 leas, or 3,000 yards; 20 hanks contain consequently 60,000 yards; and these constitute one bundle. It is by the standard lea of 300 yards that the description of yarn is known. Thus "No. 20" contains 20 leas per pound weight. The bundles are arranged in bunches, containing 3, 6, 9, or 12 bundles apiece, according to the fineness of the quality.

The *drying* of the wet-spun yarn is effected either in lofts, heated by steam up to 90° F., or by exposure in the open air upon poles. When brought from the drying, the yarns are *made up*, so as to feel soft and supple, by twisting them backward and forward and stretching them. They are then folded and are ready for sale.

*Thread*, in its technical sense, is the compound cord produced by doubling and twisting two or more single lines of yarn. The thread-frame closely resembles the throstle-frame used for spinning linen yarn, but the water-troughs are smaller, and there are only two rollers, which are placed one above the other. The lines of yarn delivered by the bobbins (which are set closely upon their respective skewers on a creel, or shelf, extending along the whole length of the machine) descend over a glass rod into the water-trough, where they get wetted. On emerging, they are guided along the bottom of the under roller, and, passing between it and the upper roller, turn round the top of the latter, whereon they are laid parallel. From the upper roller the parallel lines of yarn pass obliquely downward, through an eyelet-hole, to the flier of the spindle, the rapid revolution of which twists them into a solid cord or thread. The thread then works itself upon the bobbin, which is fitted as usual on the spindle.

Preparation of Warp.—As in the case of cotton, linen yarn goes through a series of processes, called *warping*, *sizing*, *beaming*, and *drawing in*, necessary for the purpose of preparing the warp for the weaver.

The object of *warping* is to arrange all the longitudinal lines of yarn, or warps, evenly alongside of each other, in one parallel plane. The bobbins, filled with the yarn intended for warps, are taken to the warp-mill, and placed in the warping-frame, called a "travers." One-sixth of the number of bobbins that will furnish the quantity of warp required for the length of the intended web of cloth is usually mounted in the warping-frame. The bobbins are set loosely in a horizontal position, upon wire skewers or spindles attached to the frame, so that they may revolve and give off the yarn freely. The principal machine in the mill is the warping-mule, which consists of a large reel of wood with 12, 18, or more sides, and about 7 feet in height and 6 in diameter. The external framework of the reel is mounted upon a vertical shaft, which rises in its centre. An endless band passes round the lower part of the vertical shaft, and also round a wheel placed at some little distance outside the reel, and worked by a handle. Standing (or sitting) beside the wheel, the warper turns it round, and causes the reel to revolve on the vertical shaft. The reel can be turned from right to left, or *vice versa*. The warps, converging to a focus, pass from the warping-frame to the reel through a small machine called a "heck-box," which contains 120 or more pins, made of finely-polished and hard-tempered steel. There are, in fact, as many pins as there are separate lines of warp. At the top of each is a minute eyelet-hole, through which the line of warp passes in its progress to the reel from the warping-frame. The pins are inserted alternately in two separate pieces of wood, either of which may be raised, independently of the other, by means of a small handle below. The heck-box slides up and down one (or in some mills two) of the upright posts of the warping-mule, by a simple contrivance. The top of the vertical shaft is connected with the heck-

box by means of a cord, which passes over a pulley at the top of the post. As the reel revolves from right to left, the heck-box is thus gradually raised to the top of it; and when it revolves from left to right, the heck-box is gradually lowered to the bottom. The turning of the handle of the mill therefore unwinds the warp from the bobbins in the warping-frame, and winds it spirally up and down the circumference of the reel. The use of the heck-box, with its two separate pieces of wood and their alternate rows of pins, is to divide the warps into two alternate sets of threads, one set for each of the two healds or heddles of the loom. This separation is called the "lease," and without it there would be difficulty in weaving the yarn into cloth. The process by which the lease is formed is thus described by Mr. Warden in his work on "The Linen Trade": "In commencing to wind the yarn on the reel, the threads which pass through each of the two pieces of the heck are separated by raising one piece on its slide, and they are then passed, the one portion over and the other under a guide-pin attached to the reel. The other piece of the heck is then raised, and the threads in it passed over another pin in the reel, while those in the other piece go under the same. This process is repeated each time the chain or warp is wound up or down the reel, by which means the whole warp is separated thread by thread, so as to facilitate their alternate arrangement in the heddles of the loom. At the bottom of the reel a few threads are alternately passed together in 'pinfuls' over and under two other pins, which enables the weaver, by means of an evener or very open reed with a movable top, in each opening of which a pinful of yarn is placed, to spread the warp regularly in winding on the yarn-beam of the loom. Before the warp is taken off the reel, a piece of cord is passed carefully through the yarn, close to the pins, to preserve the separation of the threads, at both ends of the warp, which separation is called the lease. In rolling the warp on the yarn-beam, the weaver begins at the end where it is divided into small pinfuls, and terminates where it is separated into alternate threads. He takes care to preserve the lease perfect throughout the entire weaving of the web by passing two lease-rods between the alternate threads and keeping them there." It only remains to add that the weaver, as he removes the warp from the guide-pins of the reel, winds it, in the form of a huge ball, round his left hand.

The next process is that of *sizing* the warp, which is subject to considerable tension and friction, and would be very likely to break if stretched in the loom in the same state in which it is spun. A dressing of size is therefore given to it, to glue together the minute fibrils of which it is composed, and thus increase its strength, tenacity, smoothness, and elasticity. Warps may be sized either by the hand or by a sizing machine. The size consists of a paste of fine flour, to which a little brine is sometimes added. The method of sizing generally used by the hand-loom weaver is to put the dressing on carefully with hand-brushes, spreading it as evenly as possible over the surface. He then employs a fan for the purpose of drying the warp. Sometimes the weaver has recourse to the more primitive method of dipping the warp into a trough filled with warm size, and then squeezing it, repeating the process until the warp is completely saturated with the size, after which he spreads it out to dry in a field or drying loft. When warps are sized by a machine, the rollers containing them are mounted on a frame at one end of it. The lines of warp pass through a kind of reel to keep them distinct, and then between two rollers covered with felt. The lower roller dips into a trough filled with size, and applies the dressing to the yarn, while the upper one squeezes out the superfluous moisture. The size is rubbed into the fibrils of the yarn, and smoothed over by means of cylindrical brushes, one of them over and the other under the yarn, and moving in an opposite direction to it. The dressed yarn is then dried by being passed over a steam-box and subjected to a current of air caused by a revolving fan. In some machines there are several steam-boxes.

The next process, that of *beaming*, consists of winding the warp round the warp-beam, better known as the "weaver's beam." The weaver unrolls the bundle of warp-yarn, passes one end of it over two slings attached to the roof, then through a funnel-mouth round a series of pegs, then backward and forward over rollers, gradually spreading it more and more open until it arrives near the warp-beam, which revolves upon iron pivots. The weaver stands beside the extended lines of warp, holding in his hand an instrument called a ravel or separator. It is a rude kind of comb composed of a block of wood, into which pieces of cane are fastened. The lines of yarn are passed between the teeth of the ravel, and by this means are distributed evenly over the warp-beam to the width to which it is desired to make the cloth.

The last process preparatory to weaving consists in drawing each separate thread of the warp first through the corresponding loop of the heddles, and then through the teeth (or dents) of the reeds. The warp-beam is suspended by its ends so as to allow the lines of warp to hang down perpendicularly. The heddles are also hung up in front of the warp-beam. The weaver sits in front of the heddles and opens their loops; his assistant sits behind, and, selecting the appropriate thread of the warp, delivers it to the weaver, who draws it through the corresponding loop of the heddles. The threads of the warp are then drawn through the teeth of the reed by a hook called the reed-hook, two threads being passed through each reed-split.

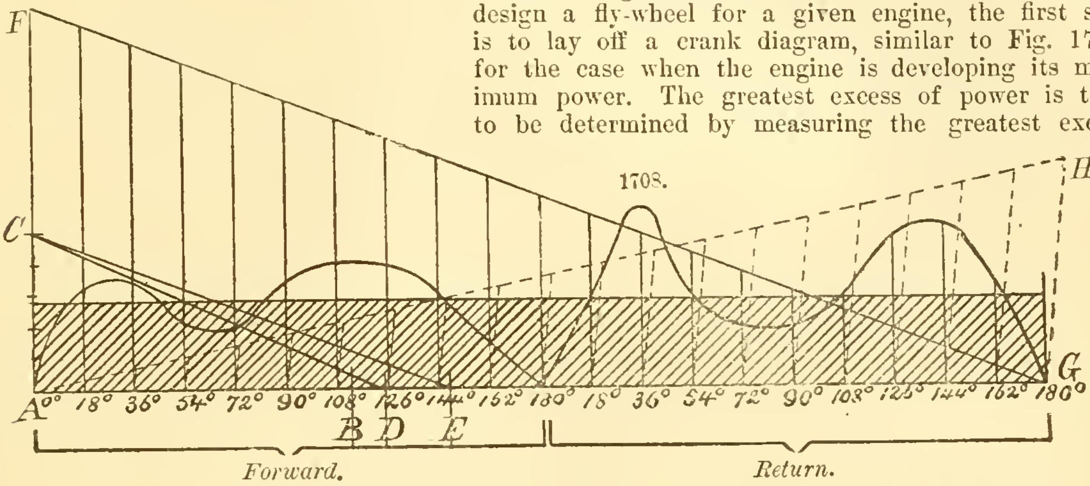
*Works for Reference.*—"Flax and its Products in Ireland," Charley, London, 1863; "The Linen Trade, Ancient and Modern," Warden, London, 1867; "British Manufacturing Industries," Bevan (from which copious extracts are embodied in the foregoing article), London, 1876. See also paper by Mr. Thomas Greenwood, "Proceedings of the Institute of Mechanical Engineers," 1865.

FLOORS. See CARPENTRY.

FLY-WHEELS. It has been shown, in discussing the action of the crank (see CRANK), that the pressure on the crank-pin throughout the revolution is unevenly distributed. It results from this that the speed of an engine will vary unless some means are provided to counteract the ill effects arising from the changing pressure. In the case of land engines, a fly-wheel is commonly attached, which is simply a wheel with a heavy rim that absorbs energy at points where it is in excess of the mean, and gives it out where the rotative effect is below the mean. Referring to Fig. 1708, it will be seen that there are portions of the curve without the mean line; and the fly-wheel should be

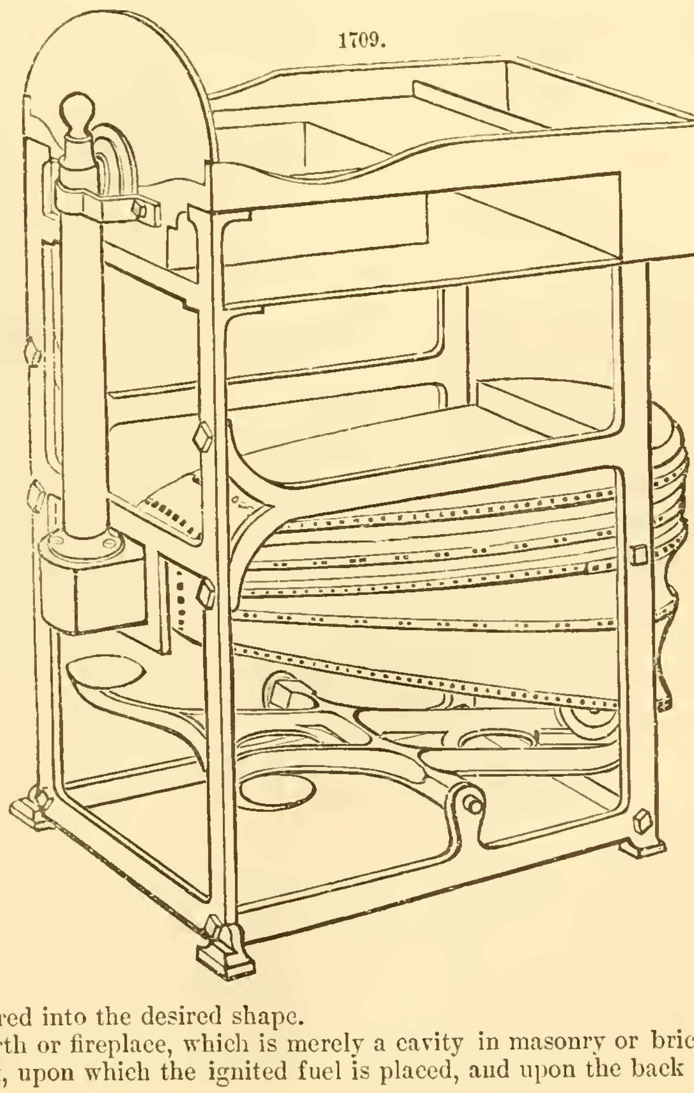
sufficiently heavy to absorb the greatest excess of power within the limits of a given variation of speed. The object of other contrivances for the regulation of speed, such as governors and adjustable cut-offs, is to control the engine under sudden variations of load, so as to make it produce at all times a crank diagram showing the same relative variation of power; but the principal office of the fly-wheel is to supply the correction for this regular variation, although it is of course useful in the case of irregular variation in the load. In order to design a fly-wheel for a given engine, the first step is to lay off a crank diagram, similar to Fig. 1708, for the case when the engine is developing its maximum power. The greatest excess of power is then to be determined by measuring the greatest excess

1708.




of area included by the curve without the mean line. If $E =$ greatest area without mean area $\div$ mean area, $v =$ velocity in feet per second of a point in the centre of the rim of the fly-wheel, $n =$ revolutions per minute, $P =$ horse-power of the engine, and $\frac{1}{m} =$ proposed variation in speed, the weight of the fly-wheel in pounds is $\frac{m \times E \times P \times 1{,}062{,}600}{v^2 \times n}$. To illustrate this rule, suppose a fly-wheel is to be designed for an engine of 50 horse-power, making 100 revolutions per minute; that the fly-wheel is to be 12 feet in diameter, and is to regulate the speed of the engine within one-fiftieth. The diameter measured from the centre of the rim can be assumed at 11.7 feet, so that $v = \frac{11.7 \times 3.1416 \times 100}{60} = 61.3$; and if it is found, on laying off the crank diagram, that the greatest excess of area is 0.25 of the mean area, the proper weight for the fly-wheel will be $\frac{50 \times 0.25 \times 50 \times 1{,}062{,}600}{3757.69 \times 100} = 1770$ lbs. The above formula can be readily adapted to the determination of the proper diameter for a fly-wheel of given weight.

1709.



FOLDING MACHINE. See Cloth-finishing Machinery, Book-folding Machine, and Printing.

FORCE. See Dynamics.

FORGE. The term forge is commonly applied to a manufactory in which iron or steel is softened by heat and worked under the hammer, or works in which the native oxides of iron are reduced without fusion to a metallic state, and then forged into blooms or bars. Forges differ from foundries and blast furnaces in their products being articles of wrought-iron, while those of the latter are castings. (See Forging, Forging Machines, Hammers, and Iron-working Machinery.) The term "forging" is equally applicable to the working of other metals, as gold, silver, and copper, when these are heated and hammered into the desired shape.

A common forge consists of the hearth or fireplace, which is merely a cavity in masonry or brick-work well lined with fire-clay or brick, upon which the ignited fuel is placed, and upon the back or

side of which a powerful blast of air is driven in through the nozzle of a double-blasted bellows, which in a common forge is generally worked by a hand-lever. Forges are sometimes constructed so as to be portable, when the bellows is most conveniently placed under the hearth; these are used in ships, and for various jobs on railways, etc.

1710.

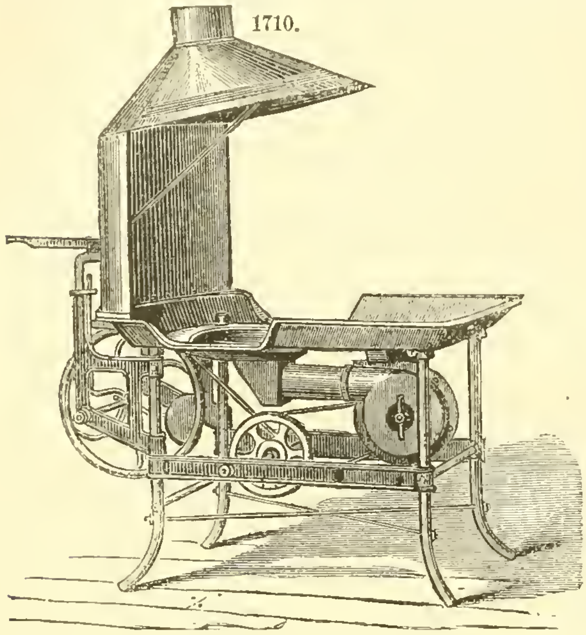
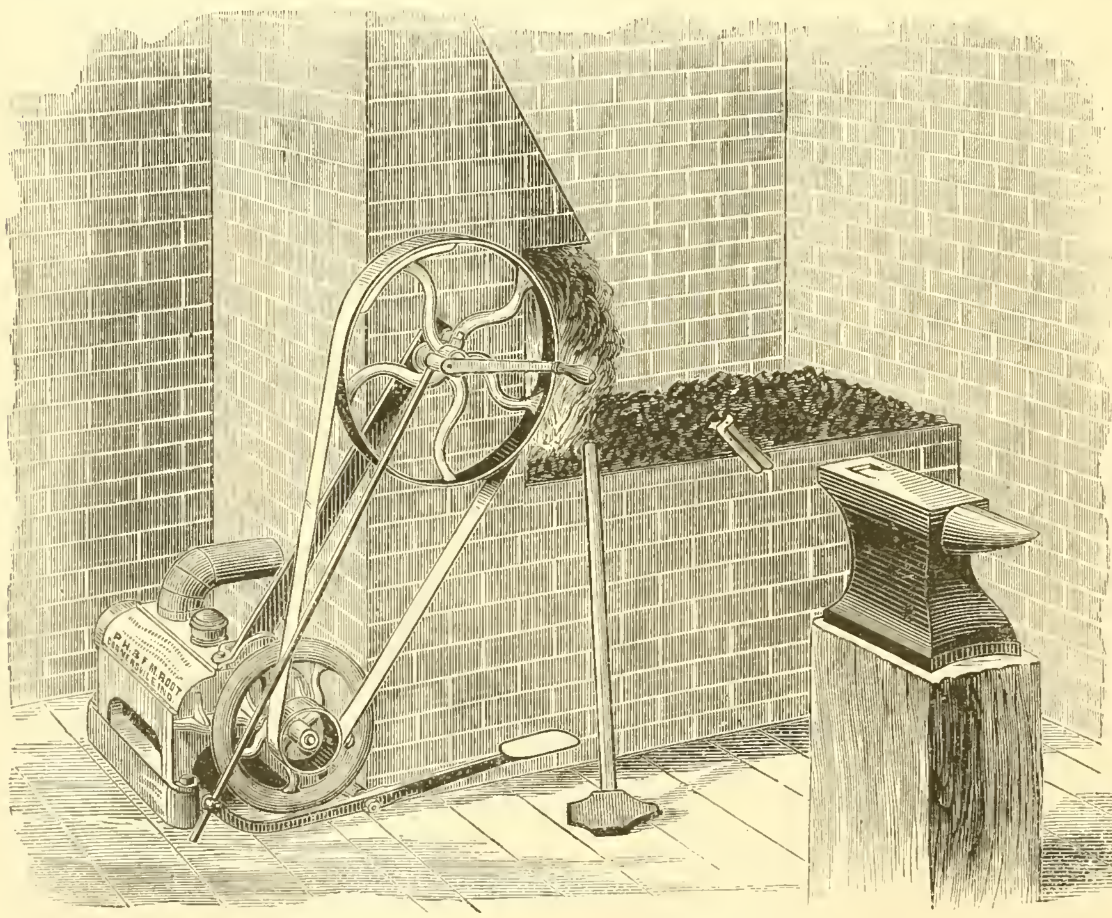


Fig. 1709 represents a portable forge made entirely of iron, and provided with a bellows placed beneath the hearth and operated by a treadle. In Patterson's forge, the blast from a bellows or blower is conducted into a lower chamber, from which it is allowed to pass to the fire by a tuyere, a valve being operated by the handle in front of the support. Fig. 1710 represents the Keystone portable forge, in which the blast is produced by a small fan-blower driven by the hand-wheel shown. The Root blower (see Blowers) has also been adapted to blowing forge fires. Its arrangement in connection with a blacksmith's forge is shown in Fig. 1711. It is claimed to equal a 36-inch to 50-inch bellows, according to size. The revolutions made are from 10 to 30 per minute. Among the advantages of using blowers for forges are, that the blast can be varied by the operator to suit the case in hand, and can be instantly stopped when no longer needed. This results in a saving of fuel and in economy of room; and it is also claimed that the tuyeres require less cleaning, and that the fire can be more rapidly rekindled, than with the ordinary bellows.

1711



FORGING. (See Axes, Forge, Forging Machines, Hammers, and Iron-working Machinery.)

In forging iron or steel the metal is in almost every case heated to a greater or less degree, to make it softer and more malleable by lessening its cohesion. Pure iron will bear an almost unlimited degree of heat; hot-short iron bears much less, and is in fact very brittle when heated; other kinds are intermediate. Of steel, shear-steel will generally bear the highest temperature, blistered steel the next, and cast-steel the least of all; but all these kinds, especially cast-steel, differ very much according to the processes of manufacture, as some cast-steel may be readily welded, but it is then somewhat less certain to harden perfectly. The smith commonly speaks of five degrees of temperature, namely: The black-red heat, just visible by daylight; the low-red heat; the bright-red

heat, when the black scales may be seen; the white heat, when the scales are scarcely visible; and the welding heat, when the iron begins to burn with vivid sparks.

Steel requires, on the whole, very much more precaution as to the degree of heat than iron; the temperature of cast-steel should not generally exceed a bright-red heat, and that of blistered and shear-steel a moderate white heat. Although steel cannot in consequence be so far softened in the fire as iron, and is therefore always more dense and harder to forge, still from its superior cohesion it bears a much greater amount of hard work under the hammer, when it is not overheated or burned; but the smallest available temperature should be always employed with this material, as in fact with all others.

The cracks and defects in iron are generally very plainly shown by a difference in color at the parts where they are heated to a dull red; this method of trial is often had recourse to in examining the soundness both of new and old forgings.

When a piece of forged work is required to be particularly sound, it is a common practice to subject every part of the material in succession to a welding heat, and to work it well under the hammer, as a repetition of the process of manufacture to insure the perfection of the iron: this is technically called *taking a heat over it;* in fact, a heat is generally understood to imply the welding heat. For a 2-inch shaft of the soundest quality, $2\frac{1}{2}$-inch iron would be selected, to allow for the reduction in the fire and the lathe; some also twist the iron before the hammering to prevent it from becoming *spilly.*

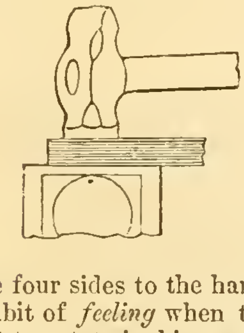
The use of sand sprinkled upon the iron is to preserve it from absolute contact with the air, which would cause it to waste away from the oxidation of its surface, and fall off in scales around the anvil. If the sand is thrown on when the metal is only at the full red heat, it falls off without adhering; but when the white heat is approached, the sand begins to adhere to the iron; it next melts on its surface, over which it then runs like fluid glass, and defends it from the air. When this point has been rather exceeded, so that the metal nevertheless begins to burn with vivid sparks and a hissing noise like fireworks, the welding temperature is arrived at, which should not be exceeded. The sparks are, however, considered a sign of a dirty fire or bad iron, as the purer the iron the less it is subject to waste or oxidation in the course of work. In welding two pieces of iron together, care must be taken that *both* arrive at the welding heat at the same moment; it may be necessary to keep one of the pieces a little on one side of the most intense part of the fire (which is just opposite the blast), should the one be in advance of the other. In all cases a certain amount of *time* is essential; otherwise, if the fire be unnecessarily urged, the outer case of the iron may be at the point of ignition before the centre has exceeded the red heat. In welding iron to steel, the latter must be heated to a considerably less degree than the iron, the welding heat of steel being lower from its greater fusibility; but the process of welding will be separately considered under a few of its most general applications, when the ordinary practice of forging has been discussed, to which we will now proceed.

The general practice in forging works from the bar of iron or steel is for the most part included in the three following modes, the first two occurring in almost every case, and frequently all three together, namely: by *drawing down*, or reduction; by *jumping* or *upsetting*, otherwise thickening and shortening; and by *building up*, or welding.

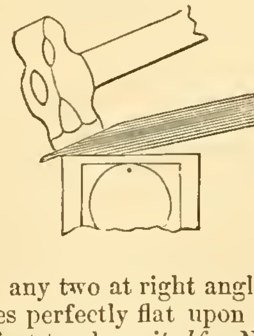
To meet the variety of cases which occur, the smith has hammers in which the penes are made in different ways, either at right angles to the handle, parallel with the same, or oblique. In order to obtain the same results with more precision and effect, tools of the same characters, but which are struck with the sledge-hammer, are also commonly used: those with flat faces are made like hammers, and usually with similar handles, except that for the convenience of reversing them they are not wedged in; these are called *set-hammers;* others, which have very broad faces, are called *flatters;* and the top tools, with narrow round edges like the pene of the hammer, are called *top fullers;* they all have the ordinary hazel-rods. (See HAMMERS.)

When the sides of the object are required to be parallel, and it is to be reduced both in width and thickness, the flat face of the hammer is made to fall parallel with the anvil, as represented in Fig. 1712; or oblique for producing taper pieces, as in Fig. 1713. Action and reaction being equal, the lower face of the work receives the same absolute blow from the anvil as that applied above by the hammer itself; it is not requisite, therefore, for works of moderate dimensions, to present every one

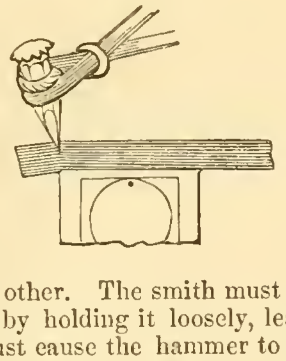
1712.



1713.



1714.



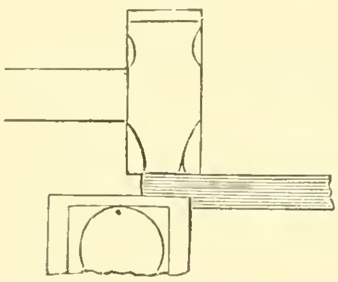
of the four sides to the hammer, but any two at right angles to each other. The smith must acquire the habit of *feeling* when the bar lies perfectly flat upon the anvil, by holding it loosely, leaving it almost to rotate in his grasp, or in fact to place *itself.* Next he must cause the hammer to fall flat upon the work. It would be desirable practice to hammer a bar of cold iron, or still better one of steel, as there would be more leisure for observations; the indentations of the hammer could be easily noticed; and if the work, especially steel, were held too tightly, or without resting fairly on the anvil, it would indicate the error by additional noise and by jarring the wrist; whereas, when

hot, the false blows or positions would cause the work to get out of shape without such monitorial indications.

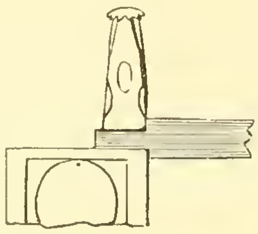
As to the best form of the hammer, there is much of habit and something of fancy. The ordinary hand-hammer is represented in Figs. 1712 and 1713; but cutlers and most tool-makers prefer the hammer without a pene, or narrow edge, and with the handle quite at the top, the two forming almost a right angle, or from that to about 80°; and sometimes the head is bent like a portion of a circle. Similar but much heavier hand-hammers, occasionally of the weight of 12 or 14 lbs., are used by spade-makers for planishing; but, the work being thin and cold, the hammer rises almost exclusively by the reaction, and requires little more than guidance. Again, farriers prefer for some parts of their work a hammer the head of which is almost a sphere; it has two flat faces, one rounded face for the inside of the shoe, and one very stunted pene at right angles to the handle, used for drawing down the clip in front of the horse-shoe. In fact, nearly a small volume might be written upon all the varieties of hammers.

Suppose it required to *draw down* 6 inches of the end of a square or rectangular bar of iron or steel. The smith will place the bar across the anvil with perhaps 4 inches overhanging, and not resting quite flat, but tilted up about a quarter or half an inch at the near side of the anvil, as in Fig. 1713, but less in degree, and the hammer will be made to fall as there shown, except that it will be

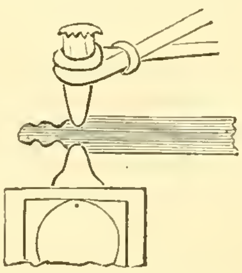
1715.



1716.



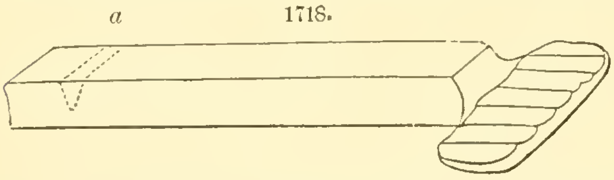
1717.



at a very small angle with the anvil. In smoothing off the work, the position of Fig. 1712 is assumed; the work is laid flat upon the anvil, and the hammer is made to fall as nearly as possible horizontally; a series of blows are given all along the work between every quarter turn, the hammer being directed upon one spot, and the work drawn gradually beneath it. In drawing down the tang or taper-point of a tool, the extreme end of the iron or steel is placed a little beyond the edge of the anvil, as in Fig. 1713, by which means the risk of indenting the anvil is entirely removed, and the small irregular piece in excess beyond the taper is not cut off until the tang is completed. Fig. 1714 shows the position of the chisel in cutting off the finished object from the bar of which it formed a part; that is, the work is placed between the edge of the anvil and that of the chisel immediately above the same; the two resemble in effect a pair of shears.

When it is required to make a *set-off*, it is done by placing the intended shoulder at the edge of the anvil: the blows of the hammer will be effective only where opposed to the anvil, but the remainder of the bar will retain its full size and sink down, as represented in Fig. 1715. Should it be necessary to make a shoulder on both sides, a flat-ended set-hammer, struck by the sledge, is used for *setting down* the upper shoulder, as in Fig. 1716, as the direct blows of the hammer could not be given with so much precision. In each of these cases some precaution must be observed, as otherwise the tools, although so much more blunt than the chisel, Fig. 1714, will resemble it in effect, and cripple or weaken the work in the corner; on this account the smith's tools are rarely quite sharp at the angles. This mischief is almost removed when the round fullers, Fig. 1717, are used for reducing the principal bulk, and the sharper tools are only employed for trimming the angles with moderate blows.

1718.



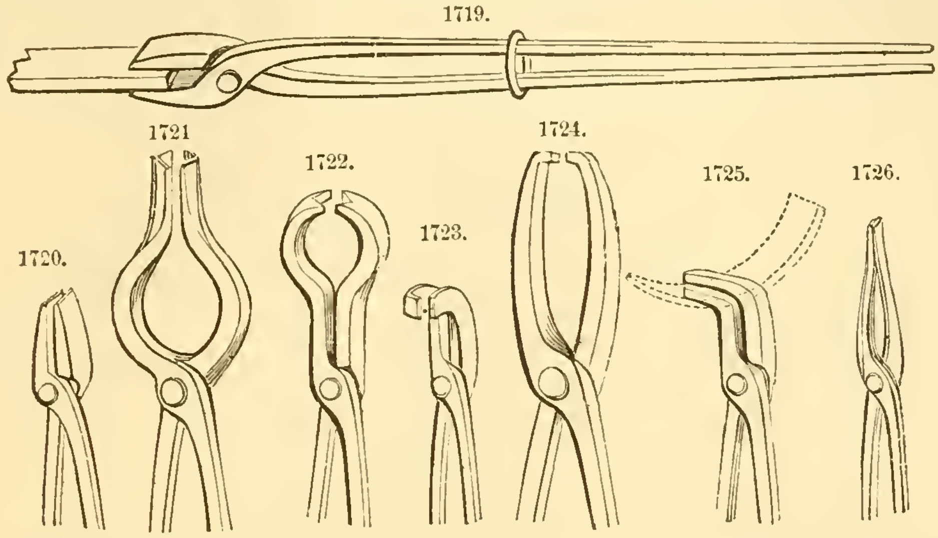

When the iron is to be set down, and also spread laterally, as in Fig. 1718, it is first nicked with a round fuller, as upon the dotted line at *a*, and the piece at the end is spread by the same tool upon the short lines of the object, or parallel with the length of the bar. The first notch greatly assists in keeping a good shoulder at the bottom of the part set down, and the lines are supposed to represent the rough indentations of the round fuller before the work is trimmed up.

*Tongs.*—Figs. 1719 and 1720 are called *flat-bit* tongs; these are either made to fit very close, as in Fig. 1720, for thin works, or to stand more open, as in Fig. 1719, for thicker bars, but always parallel; and a ring or coupler is put upon the handles or *reins*, to maintain the grip upon the work. Others of the same general form are made with hollow half-round bits; but it is much better that they should be angular, like the ends of Fig. 1721, as then they serve equally well for round bars or for square bars held upon their opposite angles. Tongs that are made long, and swelled open behind, as in Fig. 1721, are very excellent for general purposes, and also serve for bolts and similar objects, with the heads plated inward. The *pincer* tongs, Fig. 1722, are also applied to similar uses, and serve for shorter bolts.

Fig. 1723 represents tongs much used among cutlers; they are called *crook-bit* tongs; their jaws overhang the side, so as to allow the bar of iron or steel to pass down beside the rivet, and the nib at the end prevents the rod from being displaced by the jar of hammering. Fig. 1724, the *hammer* tongs, are used for managing works punched with holes, such as hammers and hatchets, as the pins enter the holes and maintain the grasp.

Fig. 1725, *hoop* tongs, are very much used by ship-smiths, for grasping hoops and rings, which may be then worked either on the edge, when laid flat on the anvil, or on the side, when upon the beak-iron; and lastly, Fig. 1726 represents the smith's *pliers*, or light tongs, used for picking up little pieces of iron, or small tools and punches.

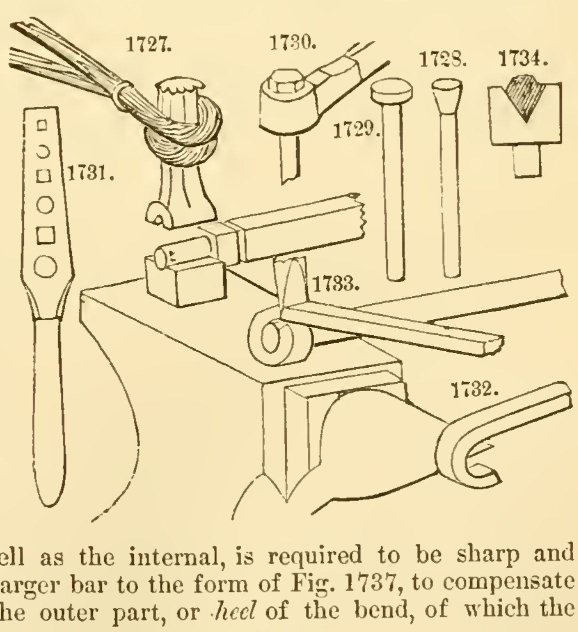
There is often considerable choice of method in forging, and the skillful workman selects that method of proceeding which will produce the result with the least amount of manual labor.




*Forging a Screw-Bolt.*—Figs. 1727 to 1730 explain the processes of making an ordinary screw-bolt. The latter is a single tool, but the heading tool, Fig. 1731, with several holes, is also used. In upsetting the end of the work, if more convenient, it may be held horizontally across the anvil, and struck on the heated extremity with the hand-hammer; or it can be jumped forcibly upon the anvil, when its own weight will supply the required momentum. If too considerable a portion of the work is heated, it will either bend, or it will swell generally; and therefore to limit the enlargement to the required spot, should the heat be too long, the neighboring part is partially cooled by immersing it in the water-trough, as near to the heat as admissible.

A bolt may be made by building up or welding. An eye is first made at the end of a small rod of square or flat iron; by bending it round the beak-iron, as in Fig. 1732, it is placed around the rod of round iron, and the curled end is cut off with the chisel, as in Fig. 1733, enough iron being left in the ring, which is afterward *welded* to the rod, to form the head of the bolt, by a few quick light blows given at the proper heat; the bolt is then completed by any of the tools already described that may be preferred. A swage at the angle of 60°, Fig. 1734, will be found very convenient in forming hexagonal heads, as the horizontal blow of the hammer completes the equilateral triangle, and two positions operate on every side of the hexagon. Fig. 1734 is essential likewise in forging triangular files and rods.

For the parts of mechanism in which a considerable length of two different sections or magnitudes of iron are required, the method by drawing down from the large size would be too expensive; the method by upsetting would be impracticable; and therefore a more judicious use is made of the iron store, and the object is made in two parts, of bars of the exact sections respectively. The larger bar is reduced to the size of the smaller, generally upon the beak-iron with top fullers, and with a gradual transition or taper extending some few inches, as represented in Fig. 1735; the two pieces are *scarfed* or prepared for welding.




*Bending Bars.*—Fig. 1735 is also intended to explain two other proceedings very commonly required in forging. Bars are bent down at right angles as for the short end or corking of the piece, Fig. 1735, by laying the work on the anvil, and holding it down with the sledge-hammer, as in Fig. 1736; the end is then bent with the hand-hammer, and trimmed square over the edge of the anvil; or when more precision is wanted, the work is screwed fast in the tail-vise, which is one of the tools of every smith's shop, and it is bent over the jaws of the vise. When the external angle, as well as the internal, is required to be sharp and square, the work is reduced with the fuller from a larger bar to the form of Fig. 1737, to compensate for the great extension in length that occurs at the outer part, or *heel* of the bend, of which the inner angle forms as it were the centre.

*Punching Holes.*—The holes in Fig. 1735 for the cross-bolts are made with a rod-punch, which is driven a little more than half-way through from the one side while the work lies upon the anvil, so that, when turned over, the cooling effect of the punch may serve to show the place where the tool

must be again applied for the completion of the hole; the little bit or *burr* is then driven out, either through the square hole in the anvil that is intended for the bottom tools, or else upon the bolster, Fig. 1738, a tool faced with steel, and having an aperture of the same form and dimensions as the face of the punch. In making a socket, or a very deep hole in the one end of a bar, some difficulty is experienced in getting the hole in the axis of the bar, and in avoiding the bursting open of the iron; such holes are produced differently, by sinking the hole as a groove in the centre of a flat bar by means of a fuller; the piece is cut nearly through from the opposite side, folded together lengthwise, and welded. The hole thus formed will only require to be perfected by the introduction of an appropriate punch, and to be worked on the outside, with those tools required for dressing off its exterior surface, while the punch remains in the hole to prevent its sides from being squeezed

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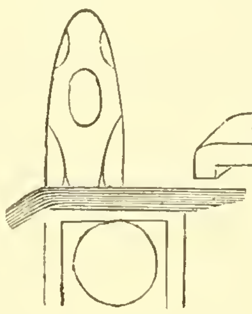

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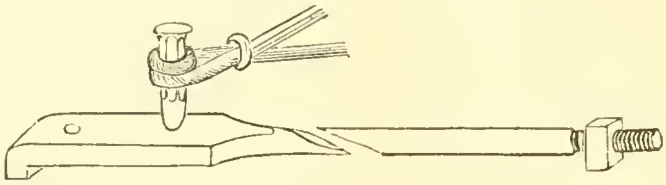

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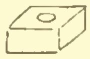


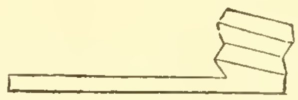
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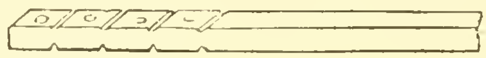
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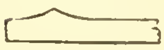
1737.



1742.

in; this method is very good. For punching square holes, square punches and bolsters are used, and the split bolster, Fig. 1739, is employed for cutting out long rectangular holes or mortises, which is often done at two or more cuts with an oblong punch.

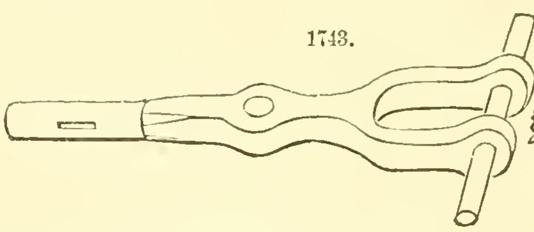
*Forging Nuts.*—Fig. 1741 shows the ordinary mode of making the square nuts for bolts. A flat bar is first nicked on the sides with the chisel, then punched, and the rough nuts, if small, are separated and strung upon the end of the poker (a slight round rod bent up at the end), for the convenience of managing them in the fire, from which they are removed one at a time when hot, and finished on the triblet, Fig. 1742, which serves both as a handle and as the means of perfecting the holes.

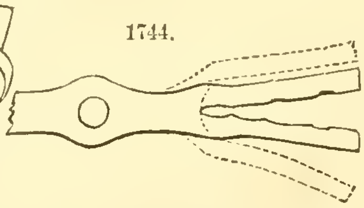
For making hexagon nuts, the flat bar is nicked on both edges with a narrow round fuller; this gives a nearer approach to the hexagon: the nuts are then flattened on the face, punched, and dressed on the triblet within the angular swage, Fig. 1734, before adverted to. Thick circular collars are made precisely in the same way, with the exception that they are finished externally with the hammer, or between top and bottom rounding tools of corresponding diameter

It is usual, in punching holes through thick pieces, to throw a little coal-dust into the hole when it is partly made, to prevent the punch sticking in so fast as it otherwise would: the punch generally gets red-hot in the process, and requires to be immediately cooled on removal from the hole.

*Various Forgings.*—When a thick lump is wanted at the end of a bar, it is often made by cutting the iron nearly through and doubling it backward and forward, as in Fig. 1740; the whole is then welded into a solid mass as the preparatory step.

A piece with three tails, such as Fig. 1743, is made from a large square bar; an elliptical hole is first punched through the bar, and the remainder is split with a chisel, as in Fig. 1744, the work at the time being laid upon a soft iron cutting plate in order to shield the chisel from being driven

1743.


1744.


against the hardened steel face of the anvil; the end is afterward opened into a fork, and moulded into shape over the beak-iron, as indicated by the dotted lines.

Such a piece as Fig. 1743, if of large dimensions, would be made in two separate parts, and welded through the central line or axis.

Should it happen that the two arms are not quite parallel, an error that could scarcely be corrected by the hammer alone, the work would be fixed in the vise with the two tails upward, and the one or other of these would be twisted to its true position by a *hook-wrench* or *set*, made like the three sides of a square, but the one very long to serve as a lever; it is applied exactly in the manner of a key, spanner, or screw-wrench, in turning round a bolt or screw.

Some bent objects, such as cranks and straps, are made from bar-iron bent over specific moulds, which are sometimes made in pairs like dies, and pressed together by screw contrivances. When the moulds are single, the work is often retained in contact with the same, at some appropriate

part, by means of straps and wedges, while the work is bent to the form of the mould by top tools of suitable kinds.

Objects of more nearly rectilinear form are cut out of large plates and bars of iron with chisels. For example, the cranks of locomotive engines are fagoted up of several bars or uses laid together, and pared to the shape; they are sometimes forged in two separate parts, and welded between the cranks; at other times they are forged out of one parallel mass, and afterward twisted with a hook-wrench, in the neck between the cranks, to place the latter at right angles. The notches are sometimes cut out on the anvil while the work is red-hot; or otherwise by machinery when in the cold state.

A very different method of making rectangular cranks and similar works is also recommended, by bending one or more straight bars of iron to the form; the angles, which are at first rounded, are perfected by welding on outer caps. In this case the fibre runs round the figure, whereas, when the gap is cut out, a large proportion of the fibres are cut into short lengths, and therefore a greater bulk must be allowed for equal strength: this method is however seldom used.

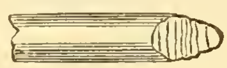
All kinds of levers, arms, brackets, and frames are made after these several methods, partly by bending and welding, and partly by cutting and punching out; and few branches of industry present a greater variety in the choice of methods, which call the judgment of the smith continually into requisition.

*Welding.*—There are several ways of accomplishing the operation of welding, which bear some little analogy to the joints employed in carpentry, more particularly that called scarfing, used in the construction of long beams and girders by joining two shorter pieces together endwise, with sloping joints, which in carpentry are interlaced or mortised together in various ways, and then secured by iron straps or bolts. In smiths' work likewise, the joinings are called *scarfs;* but from the adhesive nature of the iron when at a suitable temperature, the accessories called for in carpentry, such as glue, bolts, straps, and pins, are no longer wanted.

The scarfs required for the *shut* are made by first upsetting or thickening the iron by blows upon its extremity, to prepare it for the loss it will sustain from scaling off, both in the fire and upon the anvil, and also in the subsequent working upon the joint. It is next rudely tapered off to the form of a flight of steps, as shown in Figs. 1745 and 1746, and the sides are slightly beveled or pointed, as in Fig. 1746, the proportion being somewhat exceeded to render the forms more apparent. The

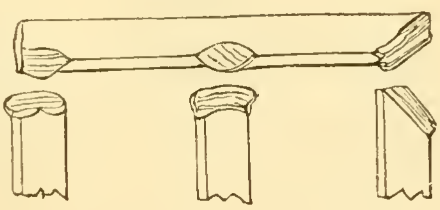
1745.

1746.



1747.

1749.




1748.

two extremities are next heated to the point of ignition; and when this is approached, a little sand is strewed upon each part, which fuses and spreads something like a varnish, and partially defends them from the air; the heat is proper when, notwithstanding the sand, the iron begins to burn away with vivid sparks. The two men then take each one piece, strike them forcibly across the anvil to remove any loose cinders, place them in their true positions, exactly as in Fig. 1745, and two or three blows of the small hammer stick them together; the assistant then quickly joins in with the sledge-hammer, and the smoothing off and completion of the work are soon accomplished. It is of course necessary to perform the work with rapidity, and literally "to strike while the iron is hot." The smith afterward jumps the end of the rod upon the anvil, or strikes it endways with the hammer; this proves the soundness of the joint, but it is mostly done to enlarge the part, should it during the process have become accidentally reduced below the general size. The sand appears to be quite essential to the process of welding, as, although the heat might be arrived at without its agency, the surfaces of the metal would become foul and covered with oxide when unprotected from the air; at all events, common experience shows that it is always required. The scarf joint, shown in Figs. 1745 and 1746, is commonly used for all straight bars, whether flat, square, or round, when of medium size.

In very heavy works the welding is principally accomplished within the fire; the two parts are previously prepared either to the form of the *tongue* or *split* joint, Fig. 1747, or that of the *butt* joint, Fig. 1748, and placed in their relative positions in a large hollow fire. When the two parts are at the proper heat, they are jumped together endways, which is greatly facilitated by their suspension from the crane, and they are afterward struck on the ends with sledge-hammers, a heavy mass being in some cases held against the opposite extremity to sustain the blows; the heat is kept up, and the work is ultimately withdrawn from the fire, and finished upon the anvil.

The butt joint, Fig. 1748, is materially strengthened, when, as is usually the case for the paddle-shafts of steam-vessels and similar works, the joint while still large is notched in on three or four sides, and pieces called *stick-in* pieces, *dowels*, or *charlins*, one of which is represented by the dotted lines, are prepared at another fire, and laid in the notches; the whole, when raised to the welding

heat, is well worked together and reduced to the intended size; this mingles all the parts in a very substantial manner. For the majority of works, however, the scarf joint, Fig. 1745, is used, but the stick-in pieces are also occasionally employed, especially when any accidental deficiency of iron is to be feared.

When two bars are required to form a T-joint, the transverse piece is *thinned down* as at *a*, in Fig. 1749; for an angle or corner the form of *b* may be adopted; but *c*, in which each part is cut off obliquely, is to be preferred. The pieces *a*, *b*, *c* are represented upside down, in order that the ridges set down on their lower surfaces may be seen. In most cases, when two separate bars are to be joined, whatever the nature of the joint, the metal should be first upset, and then set down in ridges on the edge of the anvil, or with a set-hammer, as the plain chamfered or sloping surfaces are apt to slide asunder when struck with the hammer, and prevent the union. When a T-joint is made of square or thick iron, the one piece is upset, and moulded with the fuller much in the form of the letter; it is then welded against the flat side of the bar: such works are sometimes welded with dowel or tenon joints, but all the varieties of method cannot be noticed.

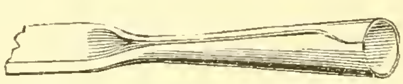
Fig. 1740 may be taken as an example in which the parts have no disposition to separate; in this and similar cases the smith often leaves the parts slightly open, in order that the very last process before welding may be the striking the whole edgeways upon the anvil, to drive out any loose scales, cinders, or sand, situated between the joints. In works that have accidentally broken in the welded part, the fracture will be frequently seen to have arisen from some dirty matter having been allowed to remain between them, on which account *shuts* or welded joints extending over a large surface are often less secure than those of smaller area, from the greater risk of their becoming foul. In fact, throwing a little small coal between the contiguous surfaces of work not intended to be united, is a common and sometimes a highly essential precaution to prevent them from becoming welded.

The conical sockets of socket chisels, garden spuds, and a variety of agricultural implements, are formed out of a bar of flat iron, which is spread out sideways or to an angle with the pene of the hammer, and then bent within a semicircular bottom tool, also by the pene of the hammer, to the form of Fig. 1750; after which the sockets are still more curled up by blows on the edges and are perfected upon a taper-pointed mandrel, so that the two edges slightly overlap at the mouth of the socket, and meet pretty uniformly elsewhere, as in Fig. 1751; and lastly, about an inch or more at the end is welded. Sometimes the welding is continued throughout the length, but more commonly only a small portion of the extremity is thus joined, and the remainder of the edges are drawn together with the pene of the hammer.

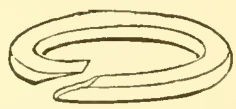
In making wrought-iron hinges, two short slits are cut lengthways and nearly through the bar, toward its extremity; the iron is then folded round a mandrel, set down close in the corner, and the

1750.

1751.



1752.



two ends are welded together. To complete the hinge, it only remains to cut away, transversely, either the central piece or the two external pieces to form the knuckles, and the addition of the pin or pivot finishes the work.

In spades, and many similar implements, the steel is introduced between the two pieces of iron of which the tools are made; in others, as plane irons and socket chisels, it is laid on the outside, and the two are afterward extended in length or width to the required size. The ordinary chisel for the smith's shop is made by inserting the steel in a cleft, as in Fig. 1747, and so is also the *pene* of a hammer; but the flat *face* of the hammer is sometimes stuck on while it continues at the extremity of a flat bar of steel; it is then cut off, and the welding is afterward completed. At other times the face of the hammer is prepared like a nail, with a small spike and a very large head, so as to be driven into the iron to retain its position, until finally secured by the operation of welding.

In putting a piece of steel into the end of an iron rod to serve for a centre, the bar is heated, fixed horizontally in the vise, and punched lengthways with a sharp square punch, for the reception of the steel, which is drawn down like a taper tang or thick nail, and driven in; the whole is then returned to the fire, and when at the proper heat united by welding, the blows being first directed as for forming a very obtuse cone, to prevent the piece of steel from dropping out.

For some few purposes blistered steel is used for welding, either to itself or to iron. It is true the first working under the hammer in a measure changes it to the condition of shear-steel, but less efficiently so than when the ordinary course of manufacture is pursued, as the hammering is found to improve steel in a remarkable and increasing degree.

For the majority of works in which it is necessary to weld steel to iron, or steel to steel, the shear, or double shear, is exceedingly suitable; it is used for welding upon various cutting tools, as most cast-steel will not endure the heat without crumbling under the hammer. Shear-steel is also used for various kinds of springs, and for some cutting tools requiring much elasticity.

It is more usual to reserve cast-steel for those works in which the process of welding is not required, although of late years mild cast-steel, or welding cast-steel, containing a smaller proportion of carbon, has been rather extensively used; but in general the harder the steel the less easily will it admit of welding, and not unfrequently it is altogether inadmissible.

The hard or *harsh* varieties of cast-steel are somewhat more manageable when fused borax is used as a defense instead of sand, either sprinkled on in powder or rubbed on in a lump; and cast-steel, otherwise intractable, may be sometimes welded to iron by first heating the iron pretty smartly, then placing the cold steel beside it in the fire, and welding them the moment the steel has acquired its

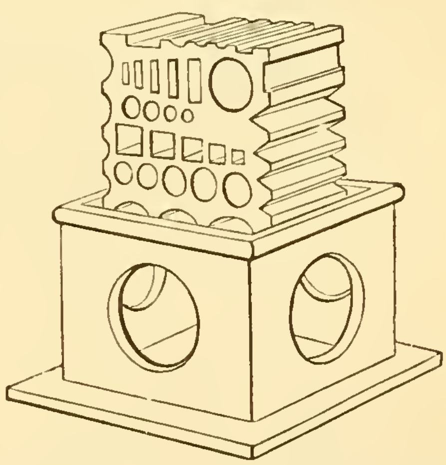
maximum temperature, by which time the iron will be fully up to the welding heat. When both are put into the fire cold alike, the steel is often spoiled before the iron is nearly hot enough, and therefore it is generally usual to heat the iron and steel separately, and only to place them in contact toward the conclusion of the period of getting up the heat. In forging works either of iron or steel, the *uniformity* of the hammering tends greatly to increase and equalize the strength of each material; and in steel, judicious and equal forging greatly lessens also the after-risk in hardening.

*Tool-Forging.*—With the utmost care and unlimited space, it would have been quite impossible to convey the instructions called for in forging the thousand varieties of tools and parts of mechanism the smith is continually called upon to produce; and all that could be reasonably attempted in this place was to convey a few of the general features and practices of this most useful and interesting branch of industry. It is hoped that such combinations of these methods may be readily arrived at as will serve for the majority of ordinary wants.

The smith in all cases selects or prepares that particular form and magnitude of iron, and also adopts that order of proceeding, which experience points out as being the most exact, sound, and economical. In this he is assisted by a large assortment of various tools and moulds for such parts of the work as are often repeated, or that are of a character sufficiently general to warrant the outlay; and to some of these we will advert.

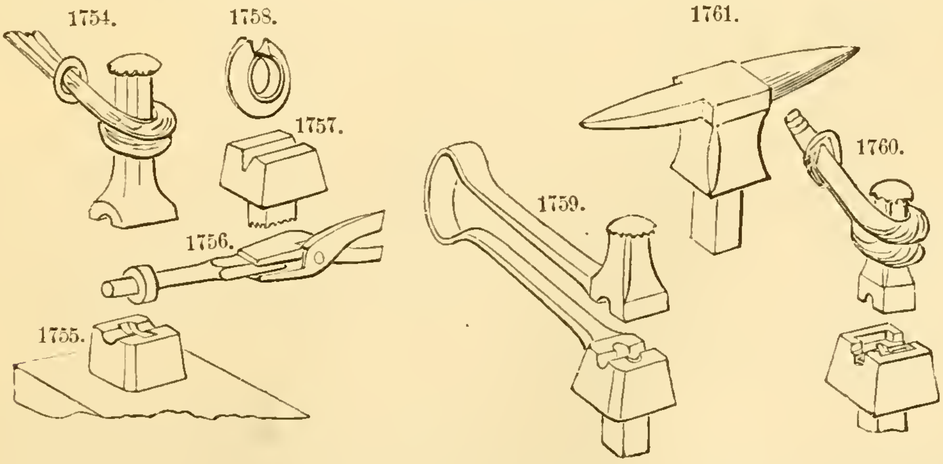
The heading tools, Figs. 1730 and 1731, are made of all sizes and varieties of forms; some with a square recess to produce a square beneath the head, to prevent the bolt from being turned round in the act of tightening its nut; others for countersunk and round-headed bolts, with and without square shoulders; many similar heading tools are used for all those parts of work which at all resemble bolts, in having any sudden enlargement from the stem or shaft. The holes in the swage-block, Fig. 1753, are used after the manner of heading tools for large objects; the grooves and recesses around its margin also serve in a variety of works as bottom swages beyond the size of those fitted to the anvil. At the opposite extreme of the heading tools, as to size, may be noticed those constantly employed in producing the smallest kinds of nails, brads, and rivets, of various denominations; some of which heading tools divide in two parts like a pair of spring forceps, to release the nails after they have been forged. These kinds are called *wrought* nails and brads, in contradistinction to similar nails cut out of sheet-iron by various processes of shearing and punching, which latter kinds are known as *cut* brads and nails.

1753.



The top and bottom rounding tools, Fig. 1727, are made of all diameters for plain cylindrical works; and when they are used for objects the different parts of which are of various diameters, it requires much care to apply them equally on all parts of the work, that the several circles may be concentric and true one with the other, or possess one axis in common. To insure this condition, some of these rounding tools are made of various and specific forms, for the heads of screws, for collars, flanges, or enlargements, which are of continual occurrence in machinery, for the ornamental swells or flanges about the iron work of carriages, and other works. Such tools, like the pair represented in Figs. 1754 and 1755, are called swage or collar tools; they save labor in a most important degree, and are thus made. A solid mould, core, or striker, exactly a copy of the work to be produced, is made of steel by hand-forging, and then turned in the lathe to the required form, as shown in Fig. 1756.

The top tool is first moulded to the general form in an appropriate aperture in the swage-block, Fig. 1753; it is faced with steel like a hammer, and the core, Fig. 1755, is indented into it, the blows of the sledge-hammer not being given directly upon the core, but upon some hollow tool previously made; otherwise the core must be filed partly flat, to present a plane surface to the




hammer. The bottom tool, which is fitted to the anvil, is made in a similar manner, and sometimes the two are finished at the same time while hot, with the cold striker between them; their edges are carefully rounded with a file, and lastly they are hardened under a stream of water.

In preparing the work for the collar-tools, when the projection is inconsiderable, the work is always drawn down rudely to the form between the top and bottom fullers, as in Fig. 1717 ; but for greater economy, large works in iron are sometimes made by folding a ring around them, as in Fig. 1733. The metal for a large ring is occasionally moulded in a bottom tool like Fig. 1757, and coiled up to the shape of Fig. 1758, after which it is closed upon the central rod between the swages, and then welded within them. The tools are slightly greased, to prevent the work from hanging to them, and from the same motive their surfaces are not made quite flat or perpendicular, but slightly conical, and all the angles are obliterated and rounded.

The spring swage-tool, represented in Fig. 1759, is used for some small manufacturing purposes; it differs in no respect from the former, except in the steel spring which connects the two parts; it is employed for light single-hand forgings. Other workmen use swage-tools, such as Fig. 1760, in which there is a square recess in the bottom tool to fit the margin of the top tool so as to guide it exactly to its true position; * this kind also may be used for single-hand works, and is particularly suited to those which are of rectangular section, as the shoulders of table-knives; these do not admit of being twisted round, which movement furnishes the guide for the position of the top tool in forging circular works.

The smith has likewise a variety of punches of all shapes and sizes, for making holes of corresponding forms; and also drifts or mandrels, used alone for finishing them, many of which, like the turned cones, are made from a small to a large size to serve for objects of various sizes. Two examples of the very dexterous use of punches are in the hands of almost every person, namely, ordinary scissors and pliers. The first are made from a small bar of flat steel; the end is flattened and punched with a small round hole, which is gradually opened upon a beak-iron, Fig. 1761, attached to the square hole of the anvil; the beak-iron has a shallow groove (not shown) for rounding the inside of the bows. The remaining parts of the scissors are moulded jointly by the hammer and bottom swage-tools; but the bows are mostly finished by the eye alone. In the Lancashire pliers, the central half of the joint is first made ; the aperture in the other part is then punched through sideways, and sufficiently bulged out to allow the middle joint to be passed through, after which the outsides are closed upon the centre. This proceeding exhibits, in the smallest kinds especially, a surprising degree of dexterity and dispatch, only to be arrived at by very great practice; and which in this and numerous other instances of manufacture could be scarcely attained but for the enormous demand, which enables a great subdivision of labor to be successfully applied to their production.† ‡

*General Hints on Forging.*—The following hints on forging have been officially published by the British Government from data given by several eminent iron-working firms:

With reference to the means of producing sound smiths' work, the most fertile sources of defects which from time to time have been experienced are: 1. The original inferior quality of the iron; 2. Improper treatment in the forging; 3. Improper treatment of articles of smiths' work in actual service.

It being most important that every condition necessary for the operation of welding should be in the highest state of perfection, this requires that the iron should be at the right welding heat, rather than over or under it; so that, if any slight delay or impediment arise in bringing the parts together, there may be, as it were, a surplus of heat to work upon; and next in importance to this is that as little scoria, or oxide, or other foreign material as possible should cling to or interpose between the surfaces about to be welded. As the welding of iron is accompanied by its combustion, and by the production of an oxide in a melting state, we must altogether get quit of this interposing material, as, ere the two pieces are laid together, it has a tendency to form as rapidly as it is swept or wiped off. But, very fortunately, in almost every case, if due care be paid to the form and manner in which the surfaces are presented together, the instant the blows are given to the parts in question, the interposing scoria is forced out, and the then perfectly pure surfaces of the welding-hot iron are so brought into intimate contact as to unite together and form one mass. There is no department of the art of forging more important than this, inasmuch as, in the majority of cases of defective welding, it is observed that the defect in question has arisen either from the scoria being shut up by means of improper forms of the surfaces, or that it has been insufficiently expressed from between the surfaces, for want of due energy in the blows of the hammer. That great attention should be paid to this is the more important and requisite, inasmuch as, in a great many cases, the system of "dab-on" welding is unavoidable in the production of certain pieces of work; and as such "dab-on" parts are generally subject to great and unfavorable strain, it is more than usually requisite to adopt the proper precautions, so as to secure the proper expression of the scoriæ, and the intimate union of the surfaces.

Much evil arises from the risk of viscid and sulphurous scoriæ clinging to the surfaces of the iron, owing to the use of raw or impure coal as the material for the smith's fire. If the coal were of a pure quality, namely, such as contains nothing but carbon and its ordinary bituminous accompaniments, the evil alluded to would be less felt; but as all coal contains, besides earthy matter, more or less of sulphur, a class of evils arises which is of a very serious nature. When we attempt to weld together two pieces of iron which have been heated in a fire formed of very sulphurous coal, not only is the quality of the iron damaged by being rendered brittle, but also its surface becomes covered with a certain substance which, in a very remarkable degree, destroys that adhesive quality which accompanies iron when at a welding heat.

When this evil exists to excess, the parts will not unite, however much they may be hammered. But although such an extreme case as this is not frequent, yet it is a question of degree, and not of

* In practice the recess in the bottom tool would be deeper, and taper or larger above to guide the tool more easily to its place; but if so drawn the figure would have been less distinct.

† The remarks on steel also refer to the necessity of good primary forging and hammering to produce homogeneity, and also to many of the other points generally admitted by practical men as being conducive to the success of hardening.

‡ Holtzapffel's "Turning and Mechanical Manipulation."

existence, so long as raw coal is used. It is therefore advisable, for those fires which admit of it, slightly to carbonize the coal in a separate oven previous to use. This is the practice in most private establishments, where the quality of the smith's work is a prime object. The practice should be discontinued of making notches in the scraps of two pieces of iron about to be welded together, as such notches afford a lodgment for scoriæ, etc.

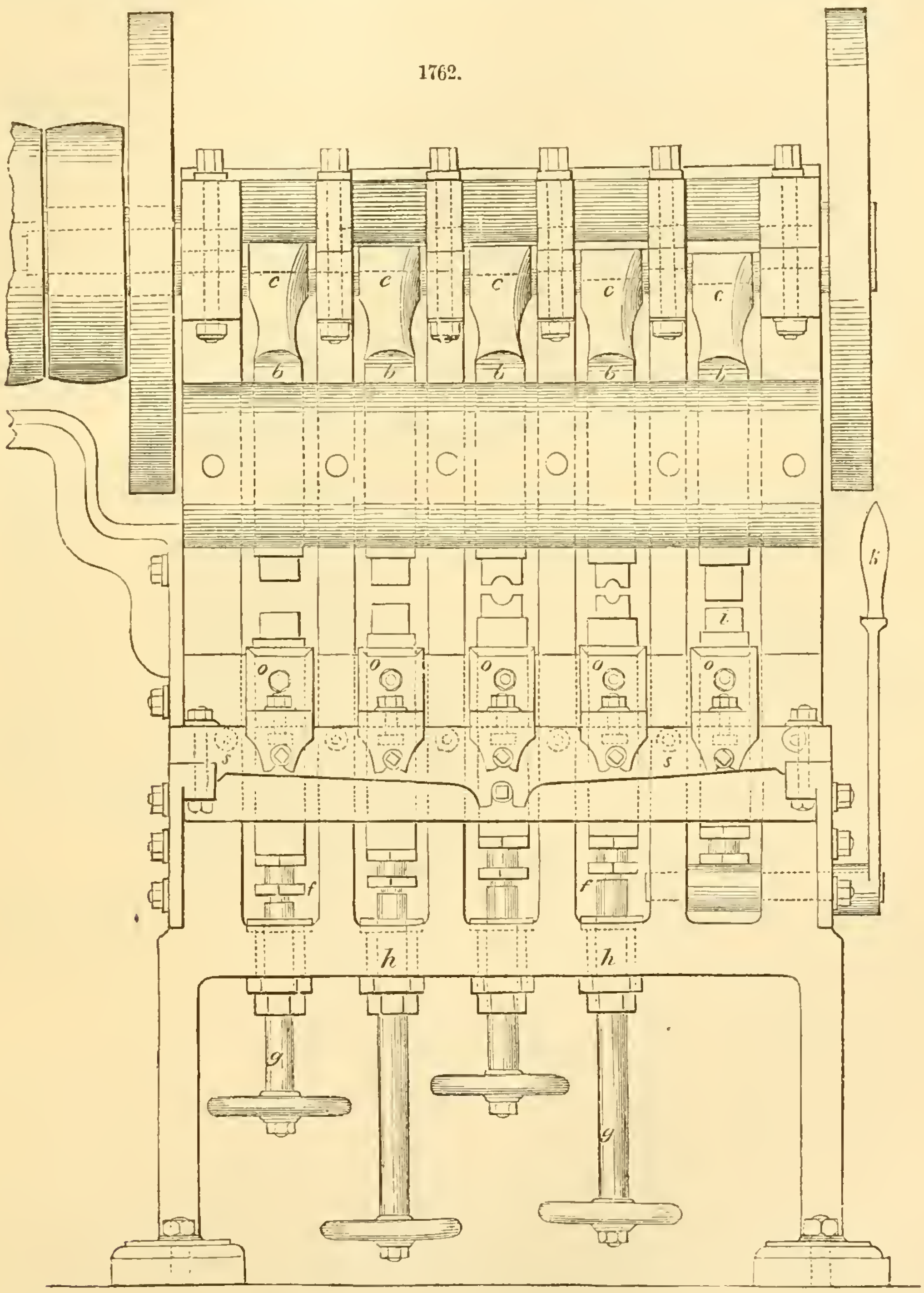
Another extremely bad practice should be discontinued, namely, that of throwing a few fresh coals into a hollow fire on the hot iron, just before the heat is coming out. The use of air-furnaces prevents this.

It is recommended also to abolish cold hammering, unless the articles can afterward be annealed.

Detailed descriptions of all forging operations will be found in "The Mechanician and Constructor," Knight, London and New York, 1869.

FORGING MACHINES. This class of machinery is especially adapted to the forging of articles of definite forms, such as spikes, rivets, nuts, horse-shoes, etc., and as such as may be distinguished

1762.

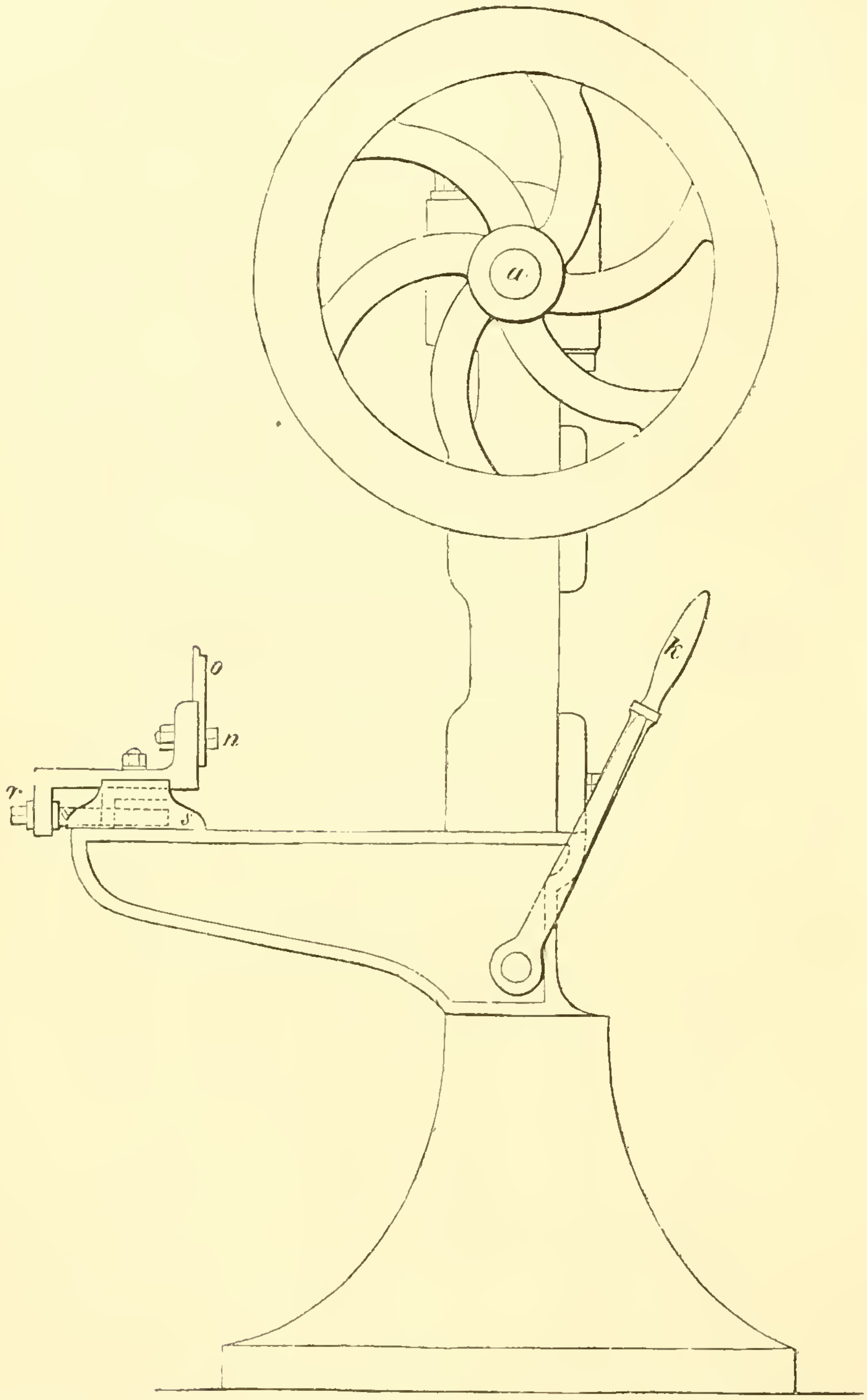



from the various forms of power hammers which perform general work. One of the oldest and most successful forging machines is represented in Figs. 1762, 1763, and 1764. Fig. 1762 is a front view, and Fig. 1763 an end view of the machine; Fig. 1764 is a section across the swages, and the apparatus connected with their motion. The machine consists of a strong cast-iron frame, carrying the driving-shaft *a*. On this shaft are forged eccentrics, which give motion to the upper swage-holders *b b*. These swage-holders are guided vertically by the frame, while the motion required by the eccentric is allowed for by the pieces *c c*, the toes of which work in the hollow on the top of the

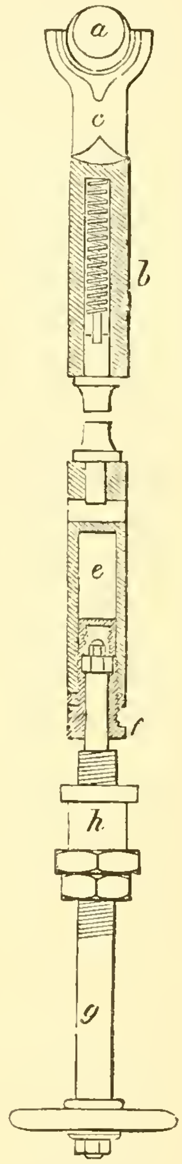
swage-holder. Each upper swage-holder is provided with a spiral spring, shown in Fig. 1764, which bears on a key fixed in the frame, and raises the swage after the eccentric has depressed it. A slot is cut in the swage-holder to allow it to slide on the key.

Machines of this class are always liable to breakage from a bar of too large a size being put between the swages. This can only be remedied by allowing some elasticity, which in this case is ingeniously effected in the following manner: A space *e*, in the lower swage-holder, is filled with cork, which can be compressed by the screw *f* to any degree of hardness. The screw *g*, which passes through the nut *h*, let into the framing, serves to raise the lower swage bodily, when it is required to vary the size of the work to be executed. The tool *i* forms a pair of shears to finish the work to a

1763.



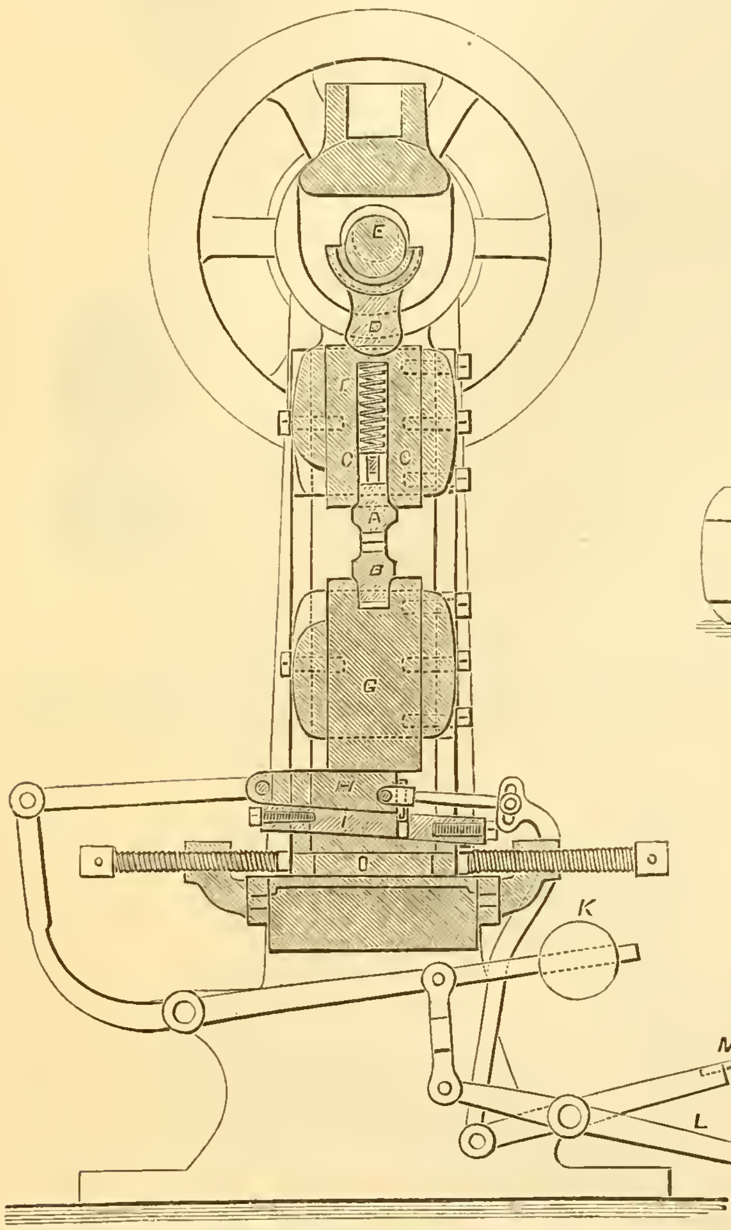

1764.




proper length, by moving the handle *k*, which, acting on an eccentric, raises the lower tool to meet the upper one. This arrangement is necessary, as, from the rapid motion of the tools, which make 600 to 700 blows per minute, it would be impossible to introduce the work without bruising it. *o o o o* are a series of rests, one being opposite to each pair of tools, which can be adjusted both in height and horizontal distance by means of the screws *n r;* the table *s s*, carrying the rests, can also be moved along the frame to facilitate the adjustment. In using the machine, the swages are adjusted so that by placing the rod of iron successively between them, it is drawn down to the size required, while the length of each part is accurately determined by placing the end of the rod in the rest. The machine cannot thus turn out the work too small, while at the same time it is so near the finished size that very little has to be taken off in the lathe.

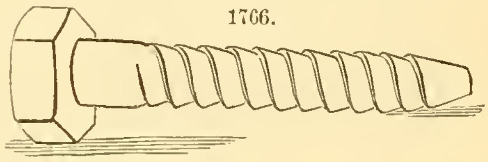
*Screw-Forging Machine.*—Fig. 1765 represents a screw-thread forging machine, devised by MM. Bouchacourt and Delille of Fourchambault, France. The rod or bolt to be threaded is placed upon the lower die $B$, and fed forward while screwing it. The upper die is mounted on a slide $C$ $C$, which is actuated in the downward direction by an eccentric $E$ on the main shaft and the toggle-bar $D$, the upward motion being obtained by an internal spiral spring $F$. The lower die $B$ is carried in a slide $G$, and is adjusted at the proper distance from the upper die by means of wedge $H$ and the inclined plate $I$ beneath slide $G$. The wedge $H$ is operated by a pedal $L$, and secured in its highest position by a bolt $J$ received in a mortise made in the plate $I$, the bolt being operated by a pedal $M$. In order to release the wedge and return it to its lowest position, the bolt is raised by pressing down the pedal $M$, whereupon the wedge is free to be returned by the counterweights $K$ in connection with pedal $L$. Slide $G$, carrying the lower die, then descends by its own gravity, and so separates the two dies sufficiently to allow of the removal of the screw bolt or rod therefrom. To compensate for the wear of the dies, and admit of their adjustment, another wedge $O$, with screw adjustment, is disposed below the inclined plate $I''$. Fig. 1766 represents the screw forged by this machine.

1765.




*Nut-Forging Machines.*—An exceedingly ingenious machine for forging nuts without waste of iron, the invention of M. Le Blanc of Paris, is represented in Fig. 1767. The principles of its operation are shown in Fig. 1768. The friction-disk $A$ is rotated in either direction by the wheels $B$, and in this way the screw $C$ is turned. This screw is stepped in the cross-bar $D$, and it causes the ascent or descent of the head $E$, to which is secured, by the rods $F$, the follower $G$. The punches, three in number, are secured to the cross-bar $D$. The dies, which are movable, are placed in slides on the follower $G$; and connected with them are the jointed levers $H$, the upper ones of which are pivoted to $D$. The dies are separately shown in Fig. 1768, and consist of a number of pieces, some pointed as at $J$, others having square ends as at $I$. By combining these as shown, the desired shape for the nut is produced. The punches are adjusted rigidly on the cross-bar $D$ and over the centres of the dies. They are of varying lengths, so that a bar placed successively under them becomes indented more and more deeply as each punch operates on the same point.

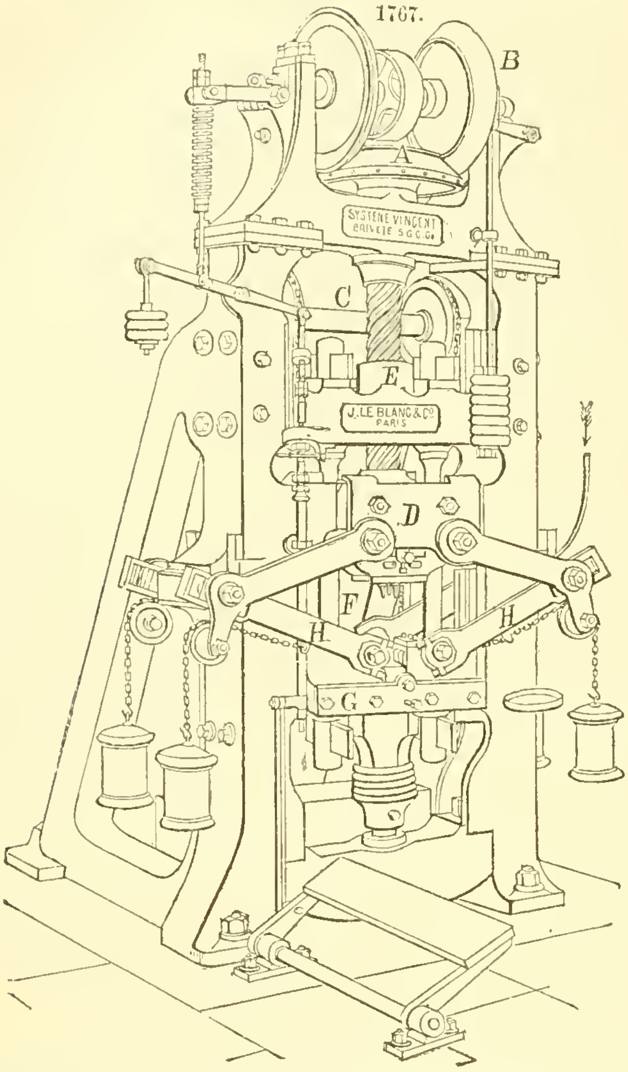
1766.



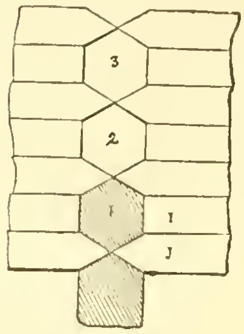
The operation of the machine is as follows: The bar of metal, being heated, is inserted between the first pair of dies, No. 1, Fig. 1768. The rotation of the screw $C$ then causes the ascent of the follower, and the jointed levers $H$ are thus caused to force the dies together, so compressing the end of the bar into the shape of a nut. While thus compressed, the ascent of the follower brings the blank so formed in contact with a punch, which produces a shallow indentation. The follower then descends, the dies open, and the operator pushes the partly-formed nut between dies No. 2, a new section of metal thus becoming exposed to the action of dies No. 1. On the rise of the follower the hole in the first nut is punched more deeply by the second punch. The bar is pushed forward once more as the follower falls for the second time, and on the last pressure the nut first formed is punched through and cut off. It will be seen that the operator has only to feed in bars to cause the continuous forging of the nuts, at the rate of from 6,000 to 10,000 per day. Bolts and spikes are similarly forged by suitable modifications of the machine.

Messrs. Taylor & Co., of Birmingham, England, have also invented a machine in which the bars are indented before being cut or punched, though in a different manner from that adopted in the

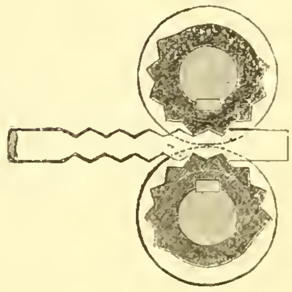
1767.




1768.

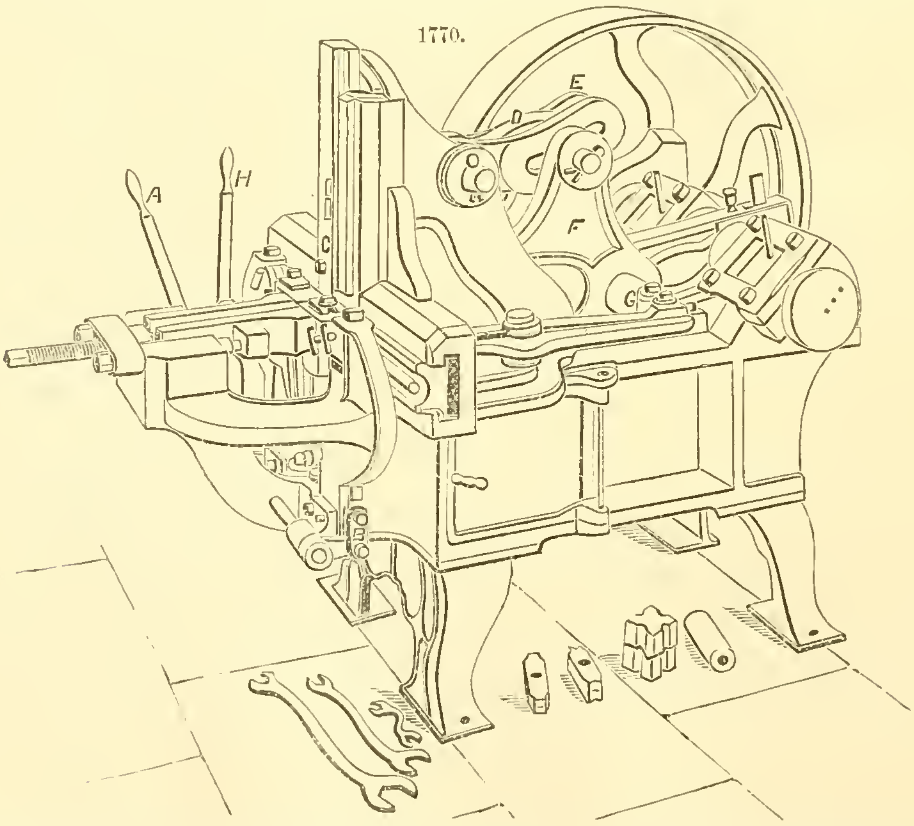



1769.



French apparatus. The principle of the indenting device, which consists of a pair of rolls geared together, will be clear from Fig. 1769. The rolls are blank for a portion of their periphery, while

1770.

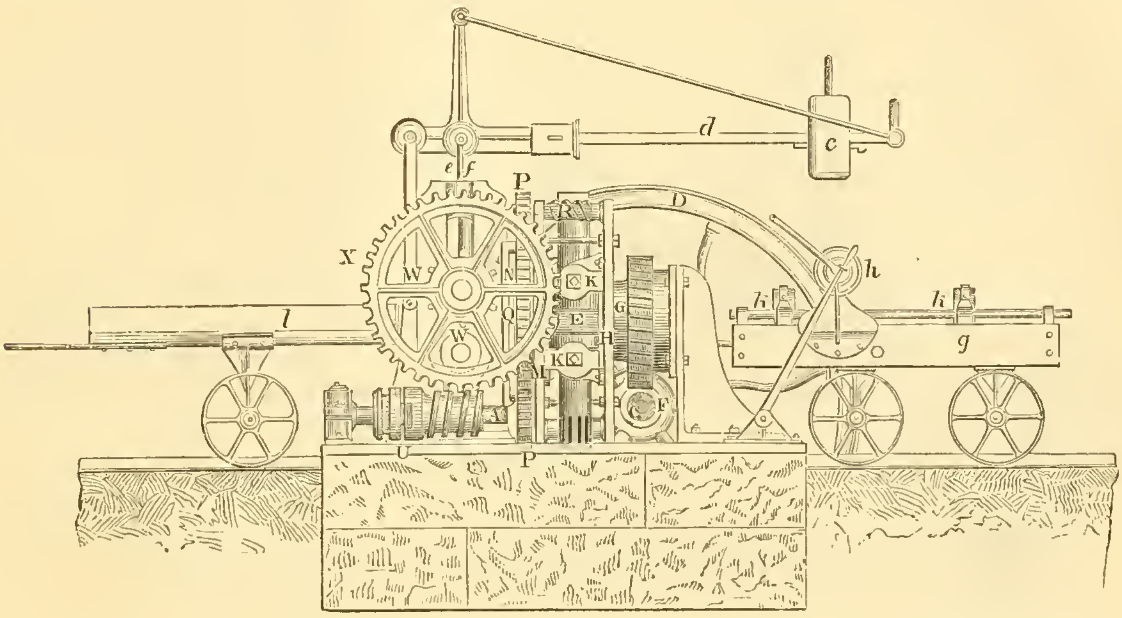



the remainder has projections or teeth formed on it as shown. In using this apparatus, the bar is heated in the ordinary way, and then thrust rapidly through the gap in the indenting rolls until

arrested by an adjustable stop. The serrated portions of the rolls then seize upon the bar and return it toward the attendant serrated as shown in the figure, the bar being thus brought to a form suitable for conversion into hexagon nuts without waste of material, while the quality of the nuts is improved.

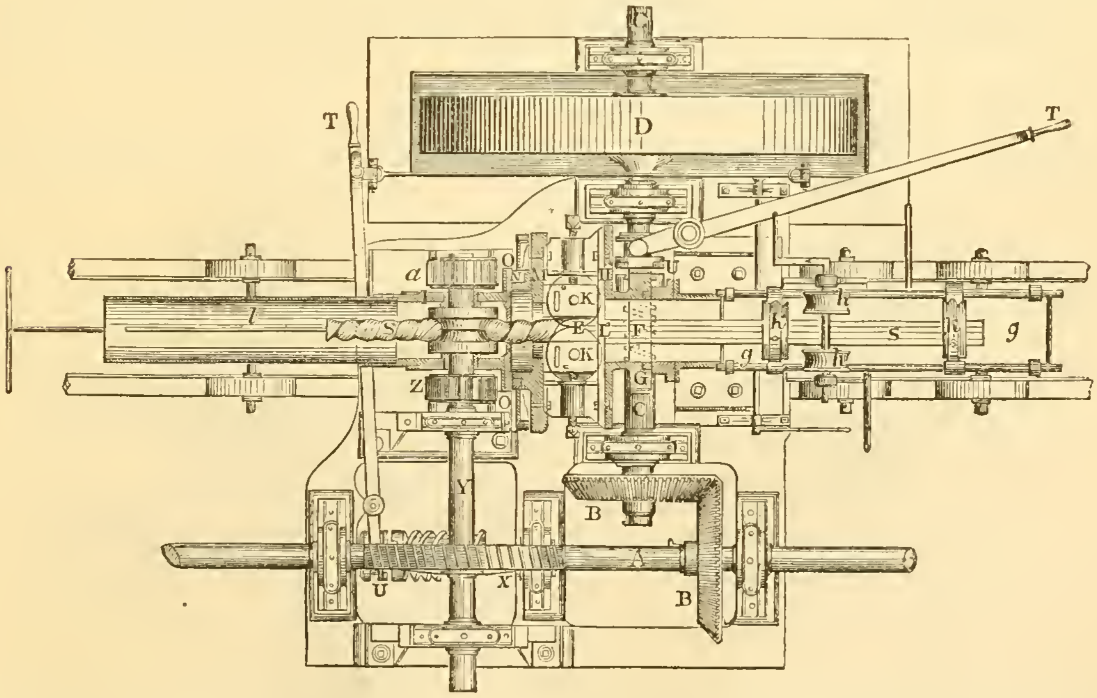
*Bolt-Forging Machine.*—Fig. 1770 represents Abbe's bolt-forging machine. The holding-vise is operated by a handle $A$ attached to the cross-shaft. On each end of the latter are the arms, having

1771.



links attached to work the sliding frame, which open the radial arms that carry the holding-dies. These holders are backed up by a filling-in piece adjusted forward by screws. The driving-wheel is constantly in operation—the machine only when it is forging on the bolt. The long slide carries the bottom die on its lower end. The top slide-die $C$ works on the face of the long slide, which is actuated by two levers $D$ $E$, having curved slots, the top die-slide having one lever with reverse curve, all working on the same pin. The pin in the upset carrier $F$ passes through the curved slots, and as it acts back and forth moves them in opposite directions. The side-dies have their motion by means of links $G$, attached to the upset carrier. When the bolt-blank is placed in the holders and clamped tightly by means of the handle $A$, the handle $H$ clutches the driving-wheel with the shaft, and the upset carrier advances by means of the connections to upset the iron, the forging dies

1772.



being all open. As the upset carrier recedes to half stroke, the side-dies compress the sides of the head; and at the extreme end of stroke the top and bottom dies act upon the other two sides of the head, and so continue to do until the bolt is finished, which is done in four revolutions of the driving-wheel. The capacity of this machine varies with the size of bolt to be forged, from 8 to 16 perfect bolts per minute.

*Twisted Forgings.*—In order to secure homogeneity, Mr. Melling, of the Rainhill Iron Works, Liverpool, proposed to twist together the bundles of constituent bars which go to form a shaft, or other forging of large size, and devised a machine for the purpose, which is herewith represented.

Fig. 1771 is a complete longitudinal elevation of the machine in working order, having the front heavy driving gearing removed to avoid obscuring the twisting details. In the same view are also shown the carriages on which the bars under treatment are conveyed to and from the machine.

1773.

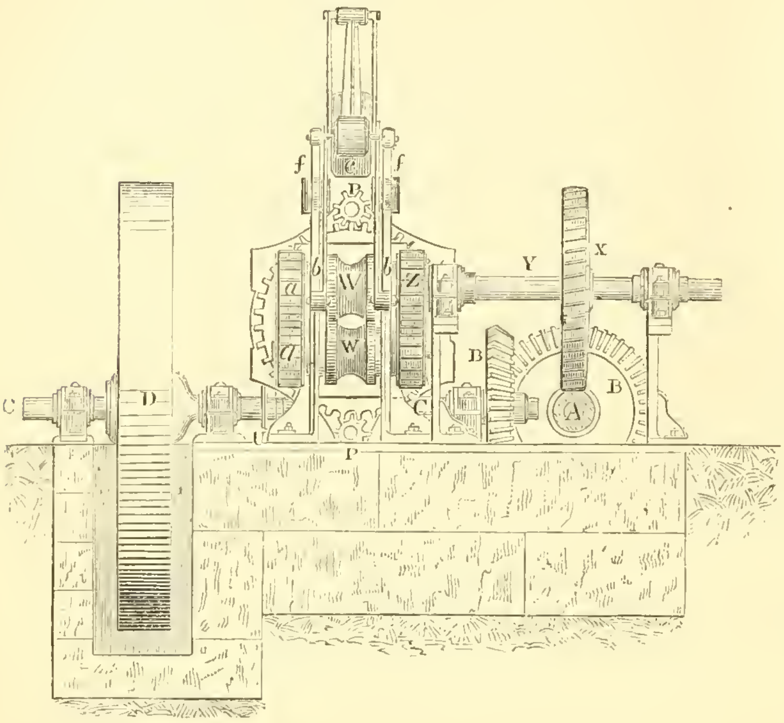



Fig. 1772 is a corresponding plan, partly in section, showing the driving gearing. In this view a bar is represented as in the act of passing through the twisting rollers.

Fig. 1773 is an end view, looking upon the delivering rollers.

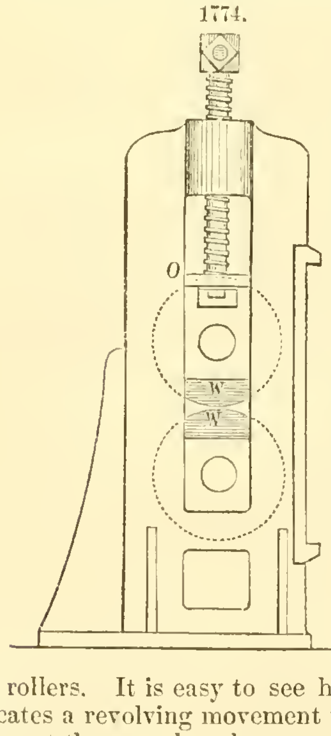
Fig. 1774 is a side elevation of a modification of the delivering rollers, differing slightly from the same portion in Fig. 1773 in point of regulation of the upper roller-bearing.

Fig. 1775 is a front elevation of the first or revolving set of rollers, exhibiting the actuating mechanism whence the revolving movement round the axis of the twisting bar is obtained.

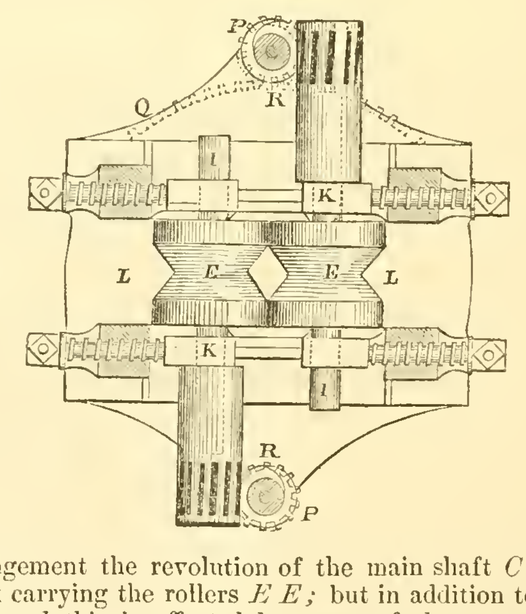
Figs. 1776 to 1780 represent various kinds of work, as finished from the original pile of bars.

The machine stands upon a massive foundation of masonry, to the surface of which the cast-iron bed-plate is bolted. The driving power is communicated to the shaft $A$, from which motion is communicated through the pair of wheels $B$ $B$ to the transverse shaft $C$ $C$, passing right across the machine, and having a heavy fly-wheel $D$ at its opposite end. From this shaft the first pair of rollers $E$ $E$, from their peculiar movement distinguished as the *revolving rollers*, are worked by the worm $F$, which gears with the large worm-wheel $G$, cast in one piece with the back of the plate $H$, and bored out at the back to work upon a fixed carrier bolted to an upright bracket fixed to the back part of the bed-plate. The shafts $T$ $T$ carrying these rollers are supported in four bearings $K$ $K$, fitted into a pair of transverse cheeks $L$ $L$, bolted and keyed between the two plates $H$ $M$. The latter is supported by a corresponding plate $N$, into which is fitted a turned ring cast on the front of the plate $M$, and this plate $N$ is again bolted to flanges $O$ $O$ on the upright cheeks of the deliv-

1774.




1775.



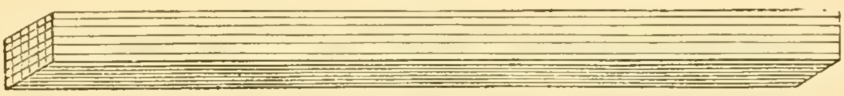

ering rollers. It is easy to see how by this arrangement the revolution of the main shaft $C$ communicates a revolving movement to the framework carrying the rollers $E$ $E$; but in addition to this movement they revolve also round their own axes, and this is effected by means of the two plates $H$ and $M$, which carry round with them two small spur-pinions $P$ $P$, gearing with the fixed toothed

rim $Q$. This motion is then transmitted from these pinions to the rollers, through the two worms $R$ $R$ upon their shafts, to the two worm-wheels cut upon the roller-shafts.

In the plan, Fig. 1772, the machine is shown as thrown out of gear with the driving-shaft, while a bar $S$ $S$ is passing-through. This disengagement is effected by the two lever-handles $T$ $T$ acting each one upon a clutch-box, corresponding with similar clutches on worms, the latter being that through which motion is communicated to the front delivering rollers, which latter may be thrown into or out of gear by the attendant, when on the opposite side of the machine, by means of a short handle. The lower of the two delivering rollers $W$ $W$, which simply revolve round their own axes, receives its motion from the main shaft, through the worm gearing with the worm-wheel $X$ on the second transverse shaft $Y$, carrying a pinion $Z$ gearing with a similar one on the lower roller-shaft. The object in giving motion to the lower roller first is to admit of the raising and lowering of the upper one as may be required to suit the work, the upper being driven from the lower one by the pair of pinions $c$ $c$ on the opposite side of the roller-standards $b$ $b$. In the combined views of the machine, the pressure upon the upper delivering roller is represented as obtained from the weight $e$, adjustable on the long lever $d$ having its fulcrum at $e$, and pressing upon the journals of the upper roller by the two spindles $f$ $f$. Crane-power may be applied to raise or lower this weighted lever, by attaching a chain to either of the two loops formed for the purpose, both on the weight and on the lever. In Fig. 1771 the office of this weighted lever is represented as supplied by a pair of adjusting screws pressing upon the upper roller-bearings.

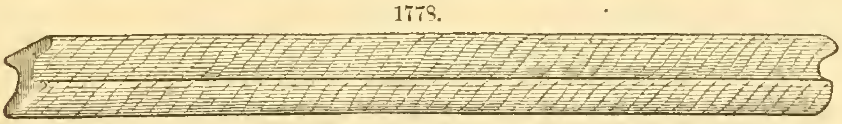
The bars to be operated upon are brought from the furnace in the carriage $g$ $g$, running upon four wheels on a tramway. The body of this carriage carries two brackets supporting a cross-shaft, on which are two pulleys $h$ $h$, employed for the withdrawal of the bars from the furnace. The pulley-shaft is worked by a short winch-handle, as in Fig. 1772, and the ends of the two chains, coiled on the pulleys, are attached to a box which is slipped over the bar while in the furnace. Guides are

1776.

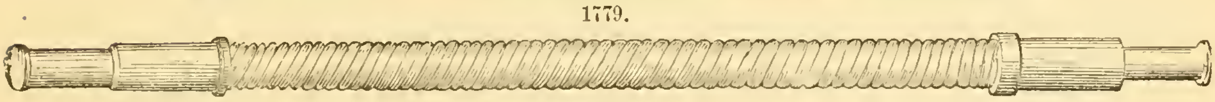


1777.

1778.



1779.



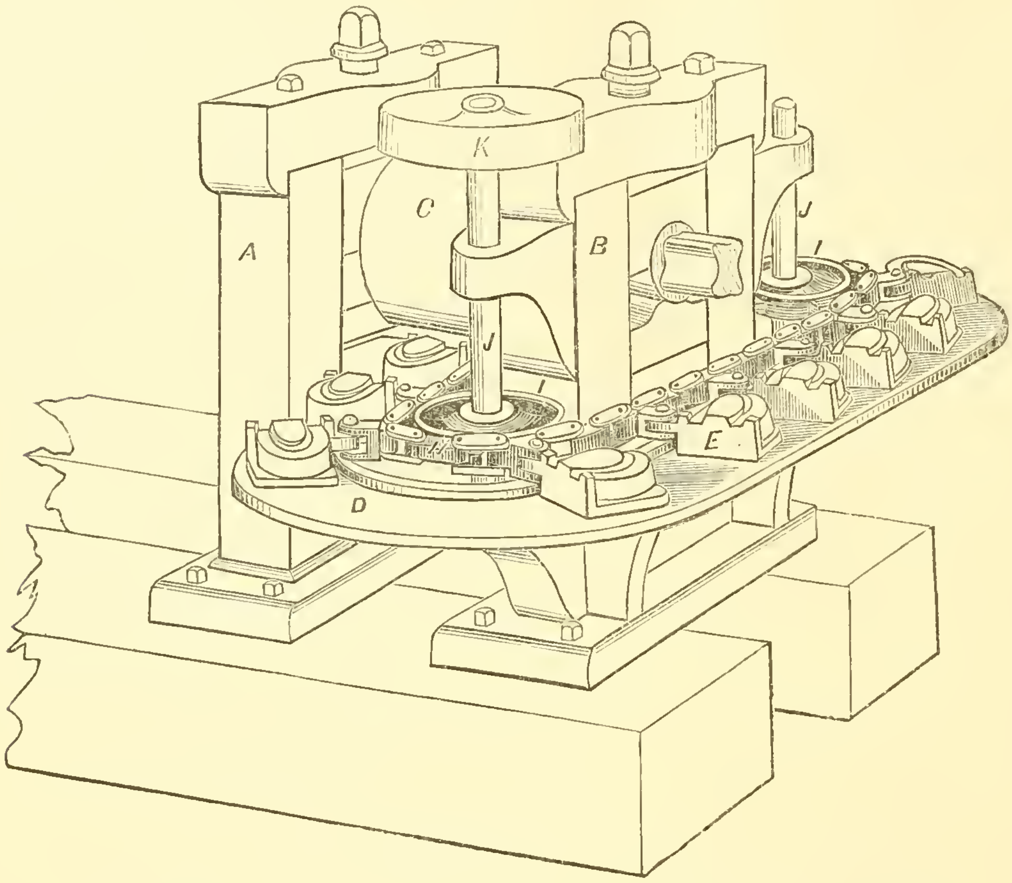
1780.

attached to the carriage at $k$ $k$ for the support of the bar or pile of bars to be twisted; and to admit of their free revolution they are turned on the outside and fitted into the cast-iron rings, bored to correspond. These bearing-rings are put together in halves, and are carried upon a pair of parallel longitudinal rods connected with the body of the carriage, or they may be simply suspended from a crane. The carriage for receiving the twisted bar, as delivered from the machine, is at $l$ on the opposite or delivering end. It is nothing more than a semicircular iron trough, mounted upon a pair of wheels, with a drawing handle. The bar or pile of bars being entered between the revolving rollers, and passed through until the end reaches the delivering pair, the upper one of this latter pair is pressed hard down upon it, so as to prevent it from turning. Being thus firmly held at this end while the after portion is carried round by the revolvers, it is clear that a twist must take place, and so the simultaneous revolutions of each pair upon their own axes carry forward the bar; it is preserved perfectly straight, and an even and regular twist is given to it. Fig. 1776 is the original pile of rectangular bars; Fig. 1777 represents these bars as twisted together previous to the subsequent finish under the hammer. In Fig. 1778 the twisted metal is shown under the form of a double T rail. Fig. 1779 is an axle formed out of round bars twisted together, and welded only at each end for the wheels and journals. Fig. 1780 is a tire-bar exhibiting the striated texture, as in Fig. 1778.

*Horseshoe-Forging Machines.—Walker's Machine* consists of one or more detachable independent and automatically traveling horseshoe-dies, in combination with a pair of smooth-surfaced pressure-rollers, between which the die or dies pass. Fig. 1781 is a perspective view of this machine; Fig. 1782 is a plan; Fig. 1783 is an enlarged perspective view of one of the dies; Fig. 1784 is a view of the creased and perforated blank; and Fig. 1785 is a view of the same after being bent ready to be operated upon by the machine. $A$ and $B$ are two housings to receive the journals of two horizontal rollers, the upper roller, $C$, being made adjustable up and down by any suitable means to

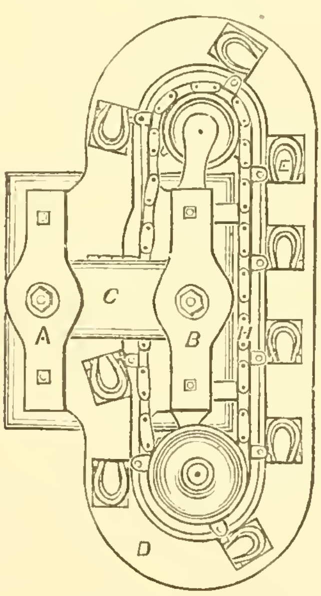
regulate the pressure thereof. $D$ represents the table or platform, over which the dies $E$ travel. These dies are connected to an endless chain or carrier $H$, passed around ordinary sprocket-wheels $I\ I$, which are secured upon upright shafts $J$; and one of these shafts is provided with a pulley or band-wheel $K$, to be run by a belt, and by which the endless chain $H$ is caused to rotate and move each die successively in between the pair of horizontal rollers, the lower roller acting as a rolling

1781.

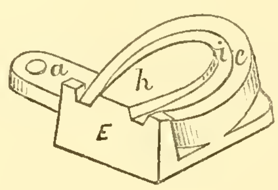



support or bed for the die, while the upper roller, $C$, is the pressure-roller for pressing the blank into the die. The die $E$ is constructed as shown in Fig. 1783, the upper surface of the die forming the frog $h$, around the toe and sides of which is a slightly-convex incline $i$, to form the required concavity on the top of the shoe. The tread $c$ of the die is made inclined, so as to be the deepest

1782.

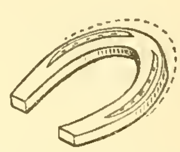



1783.




1784.

1785.



at the heel on both sides, and the highest at the toe. This tread is also gradually made wider from the quarters to the toe. The die is also provided with a joint $a$, to connect it to the endless chain.

The operation of the machine is as follows: The horizontal rollers being continuously rotated, and the endless chain set in motion so as to successively move the dies in between the rollers, the bent blanks, properly heated, are placed on the dies, and, being carried between the rollers, are by the pressure thus given caused to receive the impress of the die, and thus complete the shoe.

The process of making shoes by this machine is this: The blanks are first creased, as the iron is rolled, in the last pass of an ordinary rolling-mill; then they are cut to length; then the holes for the nails are punched; then the bent blank is operated upon as heretofore described. It is obvious that by a change in the dies various sizes and shapes of shoes can be easily made. The advantages of this process are, a better finished and shaped shoe than those heretofore produced, less waste in the manufacture, and less wear and tear of the machinery. The machine is in operation at the works of the Albany and Rensselaer Iron and Steel Company, Troy, N. Y., with an average production of 60 kegs of 100 lbs. each, every turn of 10 hours. Two boys are required to run it, one to place the shoes on the dies and one to take off.

This machine can also be used for impressing or embossing other materials as well as metals, by simply providing requisite dies. For cases where the embossing, etc., is to be done on both sides of the material, the dies are made double so as to close over the material before passing between the rollers.

In *Burden's horseshoe-forging machine* the motions are rotary and continuous. The red-hot bar is introduced at the side of the machine, and a sufficient piece is cut off by a descending cutter. The material then passes between guides to a stop, and is held in place till a bending-piece on a roller comes against it and carries it along. This piece corresponds to the inner shape of the shoe, and with this as a former the blank is carried past a series of dies which press it into shape, thinning the inner edge, thickening the heels, pinching in the heels, making the creases by dies and the nail-holes by punches in succession. After flattening, the shoe is dropped from the machine.

Other forms of machines have circular beds carrying formers, which pass the blank between dies, which act successively upon the edges and face to give the required proportions and contour as well as the creases and nail-holes. Another form pinches the heated blank between a central former and two posts, while top rollers shape it vertically, and side rollers lap the heels around the receding portion of the former, which acts as a die. In another the bar is fed in between the shears until it butts against the adjustable gauge-plate. Being severed by the shears, the bender advances and drives it between a pair of rollers, giving it a proximate horseshoe shape. The heels of the shoe fall into a depression, and as the bender retires the shoe is drawn from it. The creasing and nail punches are on an oscillating lever, and the latter acts upon and in conjunction with a lower lever which perfects the perforation.

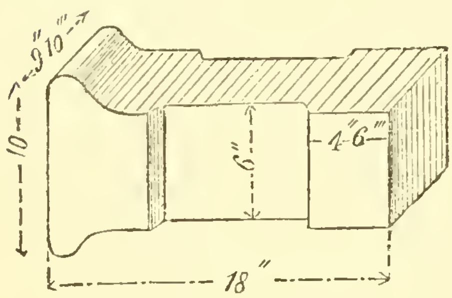
*Apparatus for Hydraulic Forging.*—This method of forging, known as "Haswell's system," is claimed to give results superior to those obtained by the ordinary methods. It consists essentially in forcing or pressing iron or steel, while at a welding heat, into suitable moulds by means of the hydraulic press, carrying a follower or "stamp" upon the end of the piston. Both the mould and the stamp are used cold. Ingots or bars may be similarly forged or drawn down without a mould upon an anvil, without giving any blow or shock, as is done of necessity when heavy steam-hammers are used.

Mr. W. P. Blake, in his "Report on Iron and Steel" at the Vienna Exposition of 1873, states that a small press examined by him with an 18-inch piston gave 600 tons pressure, and the large press with a piston of 24 inches gave 1,200 tons pressure. The pressure in the pumps was 600 atmospheres. A soft Bessemer-steel ingot, weighing 2,030 lbs., was forged under the large press, and yielded noiselessly to the pressure as if it had been putty or soft cheese. As the piston-head descends, the metal is forced each way, and the pressure visibly extends to the very centre of the mass, as shown by the movements of the lines of scale at the sides. The ends of the ingot are bulged out at the centre, and not drawn over at the surface, as is often the case with hammer-forging, which, compared with hydraulic-press forging, seems very superficial. Under the press, the whole mass of the ingot is affected. One great advantage of this method is the avoidance of great shocks, attendant upon the use of ponderous steam-hammers. In forging intricate pieces, the moulds are so made that they can be taken apart, and are held during the forging by strong bands. The follower, or stamp, is made of cast-iron. The inside of the mould is oiled with old grease from railway-boxes. A lump of white-hot steel of the proper weight is thrown in; the stamp descends upon it and forces the metal into every recess and angle of the mould. Any excess of metal rises at the sides of the stamp, and is cut off when cold. Such forgings are alike in size and weight, and, of course, require much less trimming and fitting to bring them into shape for finishing. Care is required, of course, to get the right quantity of metal, to avoid a deficiency or an excess. The method is successfully applied to the manufacture of car-wheels, the spokes and parts of the hub being forged in one piece, together with the crank-pin. Boiler-heads are made under the press in two heats. They are forced through a ring, and come out very true and perfect in form.

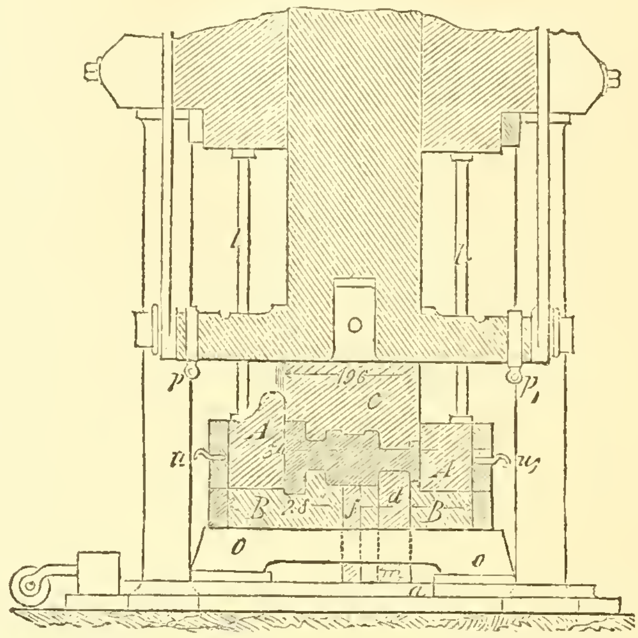
The manufacture of the parts of locomotive wheels by the process of pressure will serve as an example of the mode of operation. A wheel with 10 spokes, when made by the common methods, consists of 12 pieces, but when made by this process it is composed of but 4 pieces. We give here only a description of the manufacture of the most complicated part of the wheel, that is, the part with the crank-pin, as the other parts are made by a simpler repetition of the same process. The bloom is made in the ordinary way, from scrap-iron, and has a weight of 250 lbs. The bloom is forced under a steam-hammer (60 cwt.) into a parallelopipedon 16 inches long, 11 inches high, and 7 inches wide. While still warm it is put into the heating furnace, and when very hot is forged with the steam-hammer into the form shown in Fig. 1786. The piece is then replaced in the heating furnace preparatory to pressing. The piece is pressed in the cast-iron mould, Fig. 1787, which consists of the upper mould *A A*, the lower mould *B B*, and the die *c*. The punch *d*, which is seen in the lower mould, is kept in position by a brace. The outline of the die *c* is like that of the bottom of the mould, but with the addition of the shoulder *f*, which makes an impression to guide the subsequent perforation. The mould stands on a bed-plate *O O*, on which it can slide either to the right or left as desired. When the mould is fixed in the proper position, and the braces *l l* are fixed

so as to hold it there, and the mould thoroughly greased to facilitate the removal of the form, the piece (Fig. 1786) is placed in the mould, being taken from the heating furnace at a strong welding heat. Now follows quickly the action of the press, by which the piece is shaped. The die $c$ is raised, and a punch corresponding in shape to the piece $d$ in the lower mould is placed upon the impression made at $f$. The piece $d$ is then removed by knocking away the brace, and the piece is perforated, thus forming the spokes. By a similar process the hub is formed. The piece is removed from the

1786.



1787.



mould by the same general process before described, by raising the upper part of the mould and gently forcing the piece out. With two furnaces 24 pieces are produced in 10 hours. The expense is from 30 to 35 per cent. of the cost of forging the same under a steam-hammer.

The making of smaller wheels in one solid piece is, of course, only a repetition of the process of making segments. The whole wheel is first pressed and the spokes indented, and the interspaces afterward punched out.

FOUNDATIONS.* Foundations may be classed under two heads: 1. Ordinary foundations, on land, or protected from any considerable rush of water; 2. Hydraulic foundations, in rivers or in the sea.

To ascertain the nature of the soil on which foundations are to be laid, borings are generally taken; but they sometimes prove deceptive, owing to their coming upon some chance bowlders, or upon some adhesive clays, which, without being firm, stick to the auger, and twist it or arrest its progress, and the specimens brought up, being crushed and pressed together, look firmer than they really are. To remedy these defects, some engineers have adopted a hollow boring tool, down which water is pumped, and reascends by an annular cavity between the exterior surface of the tool and the soil, with such velocity that not only the detritus scraped off by the auger, but pebbles also, are lifted by it to the surface. This process is rapid, and the specimens, which are obtained without torsion, preserve their natural consistence. On stiff clay, marl, sand, or gravel, the safe load is generally from 55 to 110 cwt. on the square foot; but a load of 165 to 183 cwt. has been put upon close sand in the foundations of the Gorai bridge, and on gravel in the Loch Ken viaduct and at Bordeaux. On a rocky ground, the Roquefavour aqueduct exerts a pressure of 268 cwt. to the square foot.

*Ordinary Foundations.*—When the ground consists of rock, hard marl, stiff clay, or fine sand, the foundations can be laid at once on the natural surface, or with slight excavation, and with horizontal steps where the ground slopes. At the edge of steep descents, with dipping strata, it is necessary to find layers which will not slip, or, if there is such a tendency, to strengthen the layers of rock by a wall, especially when it is liable to undergo decomposition by exposure to the air, or to use iron bolts uniting the layers of rock. On ground having only a superficial hard stratum resting upon a soft subsoil, buildings have sometimes been erected by merely increasing the bearing surface, and lightening the superstructure as much as possible; but generally it is advisable to place the foundations below all the soft soil. On an uneven surface of rock a layer of concrete spread all over affords a level foundation. Sometimes large buildings have been securely built on quicksands, of too great thickness to be excavated, by the aid of excellent hydraulic mortar, and by excavating separately the bed of each bottom stone. Such a building will be stable if its pressure on the foundation is uniform throughout, and if it is placed sufficiently deep to counterbalance the tendency of the sand to flow back into the foundations. Instances of this class of foundations are to be found in sewers built on water-bearing sands, which sometimes give rise to as much difficulty as foundations built in rivers; as, for example, in the network of London sewers, and in the Metropolitan Railway. The flowing in of sand with the water in pumping, and consequent undermining of the houses above, was prevented in these cases by constructing brick or iron sumps for the

* The following article is partly abridged from a paper on "Foundations" by Jules Gaudard, C. E., in "Proceedings of the Institution of Civil Engineers," 1876.

pumps in suitable places, surrounding them by a filtering bed of gravel, and using earthenware collecting pipes, thus localizing the disturbance.

One means of reaching a solid foundation without removing the upper layer of soft soil is by piling, but piles are liable to decay in many soils. In Holland, buildings on piles of larch, alder, and fir have lasted for centuries; while in Belgium, large buildings have been endangered by the decay of the piles on which they rest. Sometimes columns of masonry support the superstructure, but, being placed farther apart than piles, it is necessary to connect them with arches at the surface for carrying the walls.

Too great care cannot be exercised in driving piles near buildings, lest they undermine the foundations of the latter. In erecting the extension of a large apartment house in New York, it was deemed advisable to drive piles for the foundations of the extension, although the existing building had stood safely without a similar foundation. The driving of 5 piles over an area 7 feet in width by 7 feet in length next to the corner pier of the old structure caused the pier to sink some 6 inches, and so endanger the front (27 feet wide and 80 feet high) that the owner was compelled to rebuild a large portion of the latter. Other and similar cases are known to have occurred in New York. See *Building News*, Sept. 24, 1875, p. 39, on this subject, in relation to the widening of London Bridge; also "Foundations and Concrete Works," Dobson, London, 1872, showing other objections to pile-driving.

To avoid the difficulty and expense of timbering deep foundations, a lining of masonry is sometimes sunk, by gradually excavating the ground underneath, and weighting the masonry cylinder, which is eventually filled in with rubble stone, concrete, or masonry, and serves as a pier. In India a similar system has been followed for centuries for sinking wells. When the stratum of soft soil is too thick for the foundations to be placed below it, the soil must be consolidated, or the area of the foundation must be sufficiently extended to enable the ground to support the load. The ground may be consolidated by wooden piles; but in soils where they are liable to decay, pillars of sand, or mortar, or concrete, rammed into holes previously bored, may be used. Artificial foundations are also formed by placing on the soft ground either a timber framework, surrounded occasionally by sheeting, or a mass of rubble-stone, or a layer of concrete, or a thick deposit of fine sand spread in layers 8 to 10 inches thick, which, owing to its semifluidity, equalizes the pressure.

A heavy superstructure is partially supported on a soft foundation by the upward pressure due to the depth below the surface to which it is carried, in the same manner that a solid floats in a liquid when it displaces a volume of water equivalent to its own weight. According to Rankine, a building will be supported when the pressure at its base is $wh\left(\frac{1+\sin.\psi}{1-\sin.\psi}\right)^2$ per unit of area, where $h$ is the depth of the foundation, $w$ the weight of the soft ground per unit of volume, and $\psi$ the angle of friction. Mr. W. J. McAlpine, C. E., in building a high wall at Albany, N. Y., succeeded in safely loading a wet clay soil with two tons on the square foot, but with a settlement depending on the depth of the excavation. In order to prevent a great influx of water, and consequent softening of the soil, he surrounded the excavation with a puddle trench 10 feet high and 4 feet wide, and he also spread a layer of coarse gravel on the bottom. When the foundation is not homogeneous, it is necessary to provide against unequal settlement, either by increasing the bearing surface where the ground is soft, or by carrying an arch over the worst portions.

*Hydraulic Foundations.*—Under this head are comprised all foundations in rivers, and where running water has to be contended with.

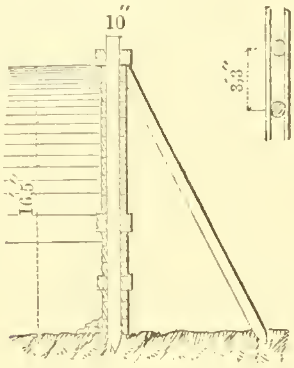
Foundations are laid upon the natural surface where it is rocky, also upon beds of gravel, sand, or stiff clay, secured against scour by aprons, sheeting, rubble-stones, or other means of protection. When the foundations are to be pumped dry, dams are resorted to if the depth of water is less than 10 feet, and are specially applicable to the abutments of bridges, where the water is less deep and rapid and the bank forms one side of the dam. The dam can be made of clay, or even earth free from stones and roots, with slopes of 1 to 1; the width at the top being about equal to the depth of water when the depth does not exceed 3 feet in a current, or 10 feet in still water.

Concrete makes a solid dam, but it is expensive to construct and difficult to remove. A coffer-dam with a double row of piles takes up less space, and is less liable to be worn away or breached, than an earth-work dam. The width of a coffer-dam is often as great as the head of water; but if the coffer-dam is strutted inside, so that the clay merely acts as a water-tight lining, the width need not exceed from 4 to 6 feet. In a coffer-dam of concrete at Marseilles constructed for the basin of the graving docks, the widths were calculated at 0.45 of the total height; the maximum width thus attained was 20 feet.

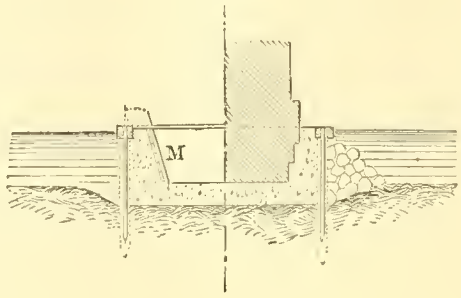
In building the viaduct of Lorient, on a foundation dry at low water, a single row of strutted piles, $3\frac{1}{2}$ feet apart, planked from top to bottom on both sides, was used (Fig. 1788), and the space between the planking, 10 inches wide, was filled with silt pressed down. When the filling is so much reduced in thickness the planks are carefully joined, and the clay is mixed with moss or tow, or sometimes with fine gravel or pounded chalk. As water leaks through joints and connections, the ties are placed as high up as possible, and the bottom is scooped out or cleaned before the clay is put in. If large springs burst out in an excavation, they must be either stopped up with clay or cement, or be confined within a wooden, brick, or iron pipe, in which the water rises till the pressure is equalized, and then it is stopped up as soon as the masonry is sufficiently advanced and thoroughly set. If, however, there is a general leakage over the whole bottom of the excavation, it must be stopped by a layer of concrete, incorporated with the foundation courses (Fig. 1789). Where there is not space for a clay dam, timber sheeting well strutted and calked is used. Hollow timber frames without a bottom, and made water-tight at the bottom after being lowered by concrete or clay, are suitable in water from 6 to 20 feet deep on rocky beds, or where there is only a slight layer of silt.

When a limit to the space occupied is immaterial, as on large rivers, a sort of double-cased crib-work dam is frequently adopted. M. Malézieux has given various details of this class of work, such as the coffer-dam in Lake Michigan to obtain the water-supply for Chicago. A caisson 200 feet long and 98 feet wide, inclosed by double water-tight sides from 13 to 19 feet high, was used at Montreal on the St. Lawrence. The interval between the two sides was about 11 feet wide, and

1788.



1789.




planked at the bottom so that the caisson could be floated into place. When the caisson was sunk, piles were driven in holes made in the bed of the river to keep it in place, and the bottom was made water-tight by a lining at the sides of beams and clay. These kinds of caissons are only suitable where the bottom is carefully leveled. Although iron caissons are generally used for penetrating some distance into the soil, there are instances of iron caissons being merely deposited upon the natural bed.

*The methods employed for laying foundations in the water*, either on the natural surface or after a slight amount of dredging, have next to be considered.

A rubble-mound foundation is sometimes employed for dams where any settlement can be repaired by adding fresh material on the top; also for landing-piers in lakes by solidifying the upper portion with concrete, and in breakwaters where a masonry superstructure is erected on the top. Such a method, however, is not suitable where a slight settlement would be injurious; and in the sea the base of the mound is generally less exposed to scour than in a river.

Another method consists in sinking a framing, not made water-tight, inside which concrete is run, and the framing remains as a protection for the concrete, and is surrounded by a toe of rubble. If the framing is of some depth, iron tie-rods are put in by divers after the bottom has been dredged, to enable the framing to support the pressure of the concrete. When piles can be driven, the framing is fixed to them. The piles, 5 to 8 feet apart, have a double row of walings fixed to them, between which close planking is driven, from 10 to 14 inches wide and from 3 to 5 inches thick; and sometimes, when the scour of a sandy subsoil has to be prevented, the planks are grooved and tongued, or have covering pieces put on by divers, or are driven in close panels. The insufficiency of a simple framing of planks for foundations on running sand was demonstrated by the destruction of the Arroux bridge at Digoin, and the Gué-Moncault bridge over the Somme by the flood of September, 1866, in spite of the fascines and rubble-stone protecting their piers, owing to the washing out of the underlying sand through small interstices by the rapid whirling current. Open framing is sometimes used for inclosing a mound of rubble-stone. These mounds require examination after floods, and renewing till the mound has become perfectly stable. In permeable soils foundations of concrete inclosed in frames are frequently employed. Lastly, concrete can be deposited *in situ* for bridge foundations. Used in sea-works, bags of concrete, like those at Aberdeen, by Mr. Dyce Cay, M. Inst. C. E., might be sometimes employed, instead of rubble-stones, for forming the base of piers or for preventing scour.

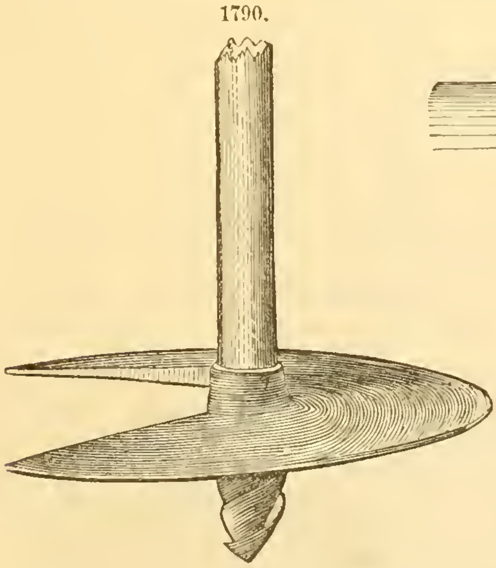
*Piles* are used where a considerable thickness of soft ground overlies a firm stratum, when the upper layer has sufficient consistence to afford a lateral support to the piles; otherwise masonry piers must be adopted. The piles are usually placed from 2¼ to 5 feet apart, centre to centre, and the distance is occasionally increased to 6½ feet for quays or other works only slightly loaded. Sometimes, under abutments or retaining walls, the piles are driven obliquely to follow the line of thrust. The Libourne bridge rests on piles 2¼ feet apart, and driven about 40 feet in sand and silt. At the Voulzie viaduct, on the Paris and Mulhouse Railway, some piles were driven 80 feet without reaching solid ground, and the ground between the piles had to be dredged, and replaced by a thick layer of concrete. Piles which have not reached firm ground sustain loads nevertheless, owing to the lateral friction; as, for instance, in the soft clay at La Rochelle and Rochefort, piles can support 164 lbs. per square foot of lateral contact, and 123 lbs. in the silt at Lorient. On the Cornwall Railway, viaducts were built upon piles 65 to 80 feet long, driven, in groups of four fastened close together, by a four-ton monkey with a small fall. A timber grating is fastened to the top of the piles, or a layer of concrete is deposited, as at Dirschau, Hollandsch Diep, and Dordrecht; or both grating and concrete, as the grating distributes the load and strengthens the piles. Planking is sometimes put on the framing which distributes the pressure, as at London Bridge; but it is considered objectionable, as it prevents any connection between the superstructure and the concrete, and increases the chance of sliding. The space between the piles from the river-bed to low water is sometimes filled with rubble-stones, and sometimes with concrete, which is less liable to disturbance. When the ground is very soft, a filling of clay has been preferred, on account of its being lighter than concrete.

A mixed system of piling and water-tight caissons, of rubble-filling and concrete, was adopted at the Vernon bridge. After the piles had been driven, the spaces between them were filled up to half the depth of water with rubble-stones; a caisson 10 feet high was then placed on the top, and a bottom layer of concrete deposited in it. In a month's time the interior of the caisson was pumped dry, the heads of the piles cut off, and the filling with cement concrete completed to low-water level. The caisson was cut off to the level of the grating as soon as the pier was well above water.

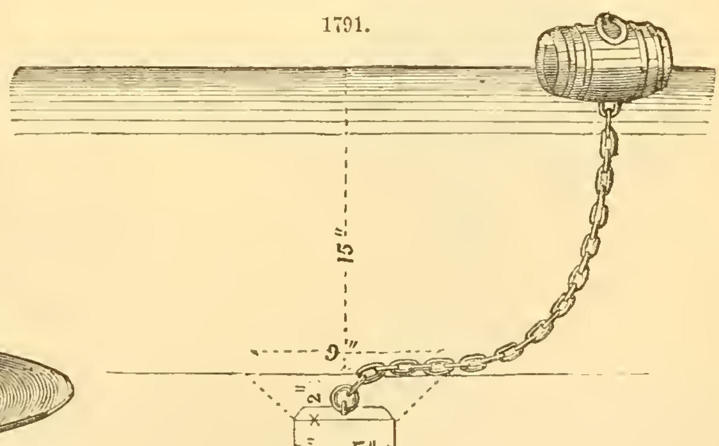
The heavy ram of Nasmyth, moved by steam, with a small fall, but giving 60 to 80 blows per minute, enables piles to be driven 33 feet in a few minutes, and with much less chance of divergence or jumping than in driving with less powerful engines. In certain soils, in which there is a momentary resistance during pile-driving, it has been proposed to bore holes in which the pile should be afterward driven. At St. Louis, the annular piles, $3\frac{1}{4}$ feet in diameter, made of 8 pieces of wood, used for guiding the pneumatic caisson, were driven by the aid of the hydraulic sand-pump working inside, the invention of Captain James B. Eads. The load that a pile driven home and secure from lateral flexion can bear may be estimated at from one-tenth to one-eighth of the crushing load, which varies between 5,700 and 8,500 lbs. per square inch. Thus, taking a fair load of 710 lbs. per square inch, a small pile of 7 inches diameter will bear about 12 tons, and a pile of 18 inches diameter will bear about 80 tons; and a pile to bear the load of 25 tons used as a unit by M. Perronet should be about 10 inches in diameter. According to M. Perronet, a pile can support a load of 25 tons as soon as it refuses to move more than three-eighths of an inch under 30 blows of a monkey weighing 11 cwt. 90 lbs., falling 4 feet, or under 10 blows of the same monkey falling 12 feet. At Neuilly, however, M. Perronet placed a load of 51 tons on piles 13 inches square, but driving the pile till it refused to move more than three-sixteenths of an inch under 25 blows of a monkey of the same weight falling $4\frac{1}{2}$ feet; but such a load is unusual. At Bordeaux the driving was stopped when the pile did not go down more than three-sixteenths of an inch under 10 blows of a monkey weighing 1,100 lbs., falling about 15 feet; but one of the piers settled considerably, the load on a pile being 22 tons; whereas at Rouen, by insisting on M. Perronet's rule, no settlement occurred. From experiments made at the Orleans viaduct, M. Sazilly concluded that piles might support with security a load of 40 tons when they refuse to move more than $1\frac{3}{8}$ inch under 10 blows of a monkey weighing 15 cwt. and falling about 13 feet. Various formulæ have been framed for calculating the safe load on piles, which are quoted in a paper by Mr. W. J. McAlpine, C. E., on "The Supporting Power of Piles," and in a paper on "The Dordrecht Railway Bridge," by Sir John Alleyne, Bart., M. Inst. C. E. If Weisbach's formula is applied to M. Perronet's rule, it appears that, assuming a safe load, the limiting set of the pile might be $3\frac{1}{4}$ inches instead of three-eighths of an inch for 10 blows; and the formula shows that large monkeys should be adopted in preference to a large fall, and in this it agrees with practice for preventing injury to the piles. In order to provide against the danger of overturning in silty ground, the ground is sometimes first compressed by loading it with an embankment, which is cut away after a few months at those places where foundations are to be built. At the Oust bridge it was even necessary to connect the piers and abutments by a wooden apron, which, for additional security, was surrounded by concrete.

*Screw-piles*, Fig. 1790, were introduced by Mr. Mitchell, M. Inst. C. E., for securing buoys. They can be applied with advantage to the construction of bollards and beacons, on account of the resistance they offer to drawing out; but as in the process of screwing down the ground is more or less loosened, judgment must be used in employing them for mooring or warping buoys. In foundations for beacons they should be screwed down from 15 to 20 feet below the level to which the shifting sand is liable to be lowered. Even when all cohesion of the ground is destroyed in screwing down a pile, a conical mass, with its apex at the bottom of the pile and its base at the surface, would have to be lifted to draw the pile out. The resistance to settlement is also increased by the bear-

1790.



1791.



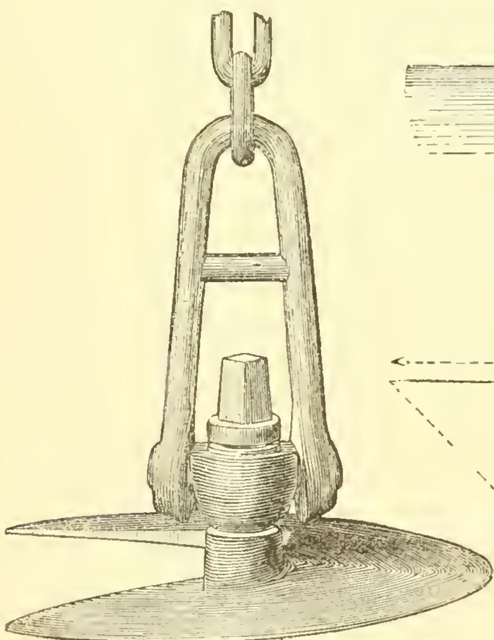

ing surface of the screw; and the screw-pile is accordingly to be preferred to an ordinary pile in soft strata of indefinite depth, or when the shocks produced by ordinary pile-driving are liable to produce a disturbance. The screw-pile has likewise the advantage of being easily taken up. Screw-piles have been principally used in England and in the United States. They have usually one or two

spirals projecting considerably from the shaft, these spirals being cylindrical for soft ground and conical for hard ground, and either of wrought-iron or of cast-iron. The shaft may be of wood, or, by preference, of iron, which must be pointed at the end for hard ground, but cylindrical and hollow when the ground is soft. The screw will penetrate most soils except hard rock; it can get a short way into compact marl, through loose pebbles and stones, and even enter coral reefs. A screw-pile turned by 8 capstan bars 20 feet long, each moved by 4 or 5 men, with a screw 4 feet in diameter, passed in less than 2 hours through a stratum of sand and clay more than 20 feet thick, the surface of which was about 20 feet below water, and dug itself to a depth of about one foot into an underlying schistous rock. At the Clevedon pier screw-piles penetrated hard red clay to depths varying between 7 and 17 feet; and although the screw had a pitch of 5 inches, they rarely went down more than 3 inches in one turn. Mr. W. Lloyd, M. Inst. C. E., has recorded an unsuccessful use of screw-piles, which in the shifting sandy bed of a South American river became twisted like a corkscrew, and were overturned in the first breaking up of the ice.

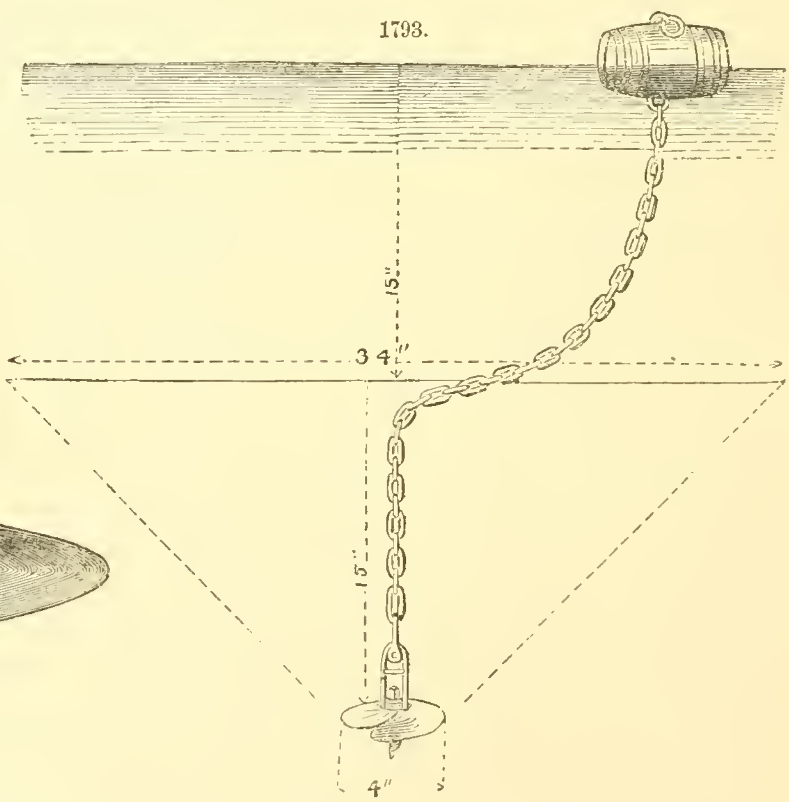
The proper area of the screw should, in every case, be determined by the nature of the ground in which it is to be placed, and which must be ascertained by previous experiment. The largest size hitherto used has been 4 feet in diameter; but within certain sizes, prescribed by the facility of manufacturing them, the dimensions may be extended to meet any case, and may be said to be limited only by the power available for forcing them into the ground. Either the screw-pile or the screw-mooring can be employed in every description of ground, hard rock alone excepted; for its helical form enables it to force its way among stones, and even to thrust aside medium-sized bowlders. In ports, harbors, estuaries, and roadsteads, rock is seldom met with, except in detached masses, the ground being usually an accumulation of alluvial deposit, which is well adapted for the reception of such foundations, and is also that in which they are generally most required.

The ground-screw has been extensively used for several purposes, and its applicability to many others will be evident from a succinct account of its present employment. The fixed or permanent moorings at present most commonly used are of two kinds—the span-chain mooring, and the sinker or mooring-block. The former of these consists of a strong chain of considerable length, stretched along the ground (across the river), and retained by heavy anchors or mooring-blocks at either end, and to the middle of the ground-chain the buoy-chain is shackled. The other kind, which is more generally employed, consists of a heavy sinker, to which a strong chain is attached, extending to a buoy shackled at the other end, Fig. 1791. This sinker, which is a block of stone or iron, is either

1792.



1793.

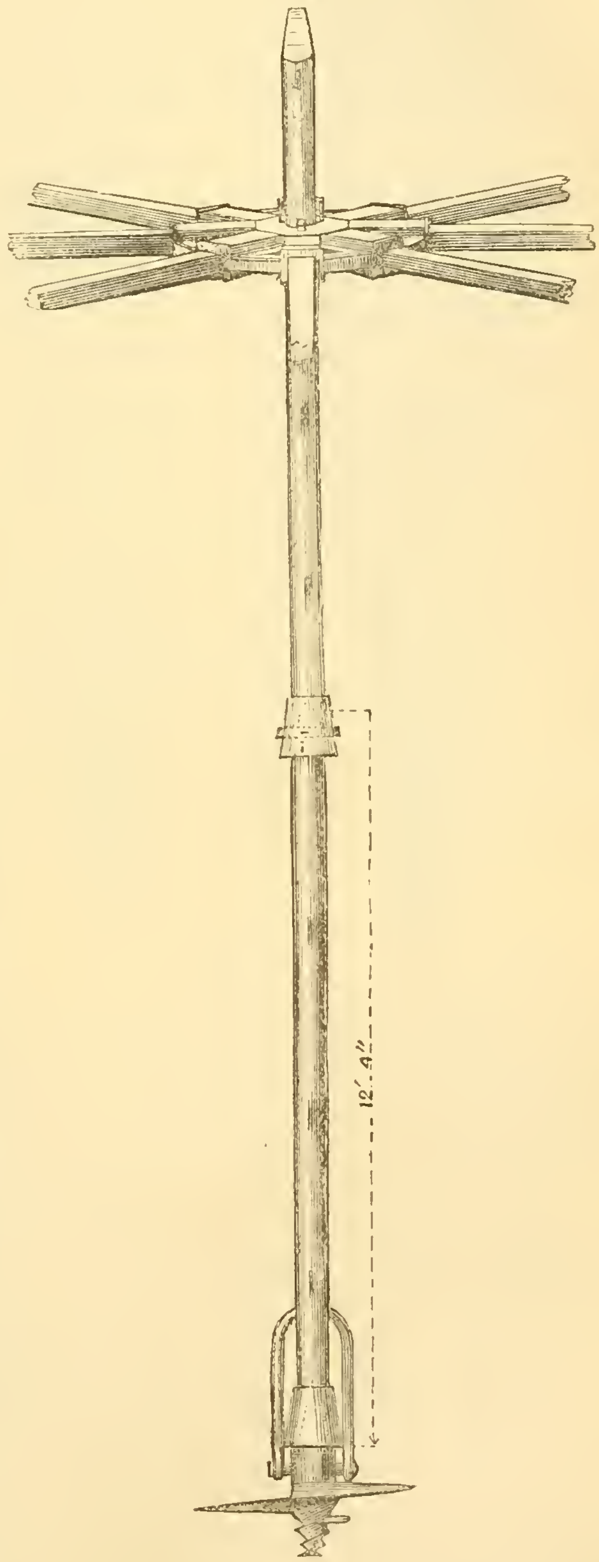



laid upon the surface of the ground, or placed in an excavation prepared for its reception. As a simple, effective, and at the same time an inexpensive mode of holding the buoy-chain down, Mr. Mitchell adopted a modification of the screw-pile, Fig. 1792, which offers great facilities for entering the ground, and when arrived at the required depth evidently affords greater holding power than any other form. Every description of earth is more or less adhesive, and the greater its tenacity, the larger must be the portion disturbed before the mooring can be displaced by any direct force. The mass of ground thus affected, in the case of the screw-mooring, is in the form of a frustum of a cone inverted, that is, with its base at the surface, the breadth of the base being in proportion to the tenacity of the ground; this is pressed on by a cylinder of water equal to its diameter, the axis of which is its depth, and the water again bears the weight of a column of air of the diameter of the cylinder. It is evident, therefore, that if a cast-iron screw of a given area be forced into the

earth to a certain depth, it must afford a firm point of attachment for a buoy-chain in every direction (Fig. 1793), and will oppose a powerful resistance even to a vertical strain, which generally proves fatal to sinker moorings, depending as they do chiefly on their specific gravity. The first trials were upon a comparatively small scale; but their success was so decisive that the merits of the moorings were acknowledged, and their use soon became extended. The depth to which these moorings have been screwed varies from 8 to 18 feet; the former is deep enough where the soil is of a firm and unyielding description, and the latter depth is found to give sufficient firmness in a very weak bottom.

The apparatus used for fixing screw-piles, Fig. 1794, consists of a strong wrought-iron shaft, in lengths of 10 or 12 feet each, connected with each other by key-joints or couplings, the lower extremity having a square socket to fit the head of the centre-pin or axis of the mooring. When the centre-pin rests on the bottom, a capstan is firmly keyed upon the shaft at a convenient height; the men then shift the capstan bars and apply their power while traveling round upon the stage, the capstan being lifted and again fixed as the mooring is screwed down into the ground. The operation is continued until the men can no longer move the shaft round, or until it is considered to have been forced to a sufficient depth.

1794.




The most important purpose to which the screw-pile has hitherto been applied to any considerable extent is for forming the foundations of lighthouses, beacons, and jetties, in situations where the soil, or sand, is so loose and unstable as to be incapable of supporting any massive structure, or where the waves have so much power of undermining by their continuous action, or beat so heavily, that the stability of any mass of masonry would be seriously endangered.

Figs. 1795 to 1798 represent various forms of screw-pile. Fig. 1795 shows the largest size, weighing 2 cwt. 3 qrs. 14 lbs., adapted for whole timber piles, which are often so splintered and shattered, and even set on fire, by the rapid blows of the steam pile-driver, when traversing compact ground, and where wrought-iron shoes are generally crushed into the timber even in ordinary ground with the force of the common pile-engine. The small screw-point opens the way for the conical part, and the larger screw not only draws the pile down, but, when it has penetrated to a sufficient depth, affords an extended base for preventing further depression. Thus several feet of timber must be saved, and the general length of the pile can be reduced, as it will bear a greater weight and offer a more solid base when introduced to a less distance, than when it rests upon the ordinary sharp, wrought-iron-pointed shoe. Fig. 1796 shows the shape adapted for railway signal-posts, and Fig. 1797 that for the supports for telegraph wires. The cast-iron screw socket-points, Fig. 1795, have been successfully applied for the supporting posts or columns of timber-sheds and buildings for railway stations and other purposes. Fig. 1798 shows the applicability to smaller objects, and a tent-pin has been selected as the most familiar example, as it requires to be removed so frequently. It also shows the use that may be made of the screw for the standards of fencing, and for an infinite number of agricultural and other purposes.

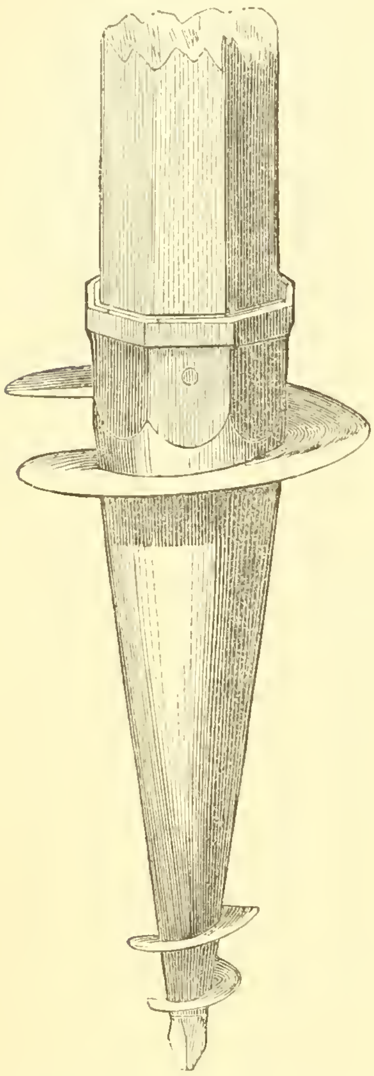
*Sheet-piles* are flat piles which, being driven successively edge to edge, form a vertical or nearly vertical sheet, for the purpose of preventing the materials of a foundation from spreading, or of guarding them from the undermining action of the weather.

Piles with disks differ little from screw-piles, except in the method of sinking them. This operation was performed at the Leven and Kent viaducts, by sending a jet of water down a wrought-iron tube inside the cast-iron pile, which washed away the silty sand from underneath the disk and caused

the pile to descend. Hollow wrought-iron piles have also been forced down by blows of a monkey in silty ground interspersed with bowlders to a depth of about 60 feet, the diameter of the piles being about 19$\frac{3}{8}$ inches. The method of cased wells is suitable where the silt is sufficiently compact and water-tight to admit of pumping the well dry, and where the depth of water is small and can easily be kept out by a coffer-dam or caisson without a bottom. (See PILE-DRIVING MACHINES.)

*Cylindrical Foundations* are sunk with or without the aid of compressed air, according to circumstances. These foundations possess the two great advantages of being capable of being sunk to a considerable depth, and of presenting the least obstruction to the current. In a clay soil the cylinder acts as a movable coffer-dam, which is sunk by being weighted, and enables the foundations inside to be built up easily and cheaply. Iron cylinders are preferred in certain cases to cylinders of brick, masonry, or concrete, on account of the ease with which they are lowered in deep water on to the river-bed, in spite of the disadvantages attaching to them of high price, of the considerable weights required for sinking them, and, lastly, of being only cases for the actual piers. The Dutch engineers have often used oval-shaped iron tubes sunk by dredging inside. Thus, in the bridge on the North Sea Canal the piers are elliptical; the one on which the opening portion turns having axes of 23 and 18 feet, and the others axes of 39$\frac{1}{2}$ and 14 feet. The horizontal flanges and ribs are larger where the radius of curvature is increased, and the vertical ribs are not continuous, but arranged so as to overlap. The bridge over the Yssel, on the Utrecht and Cologne Railway, rests upon cylinders which were sunk by internal dredging 17$\frac{3}{4}$ feet below the river-bed.

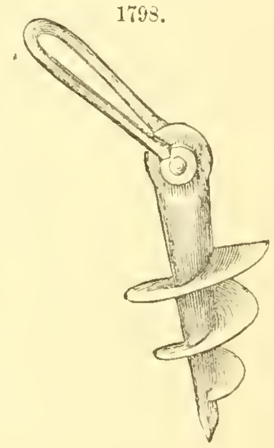
1795.



1796.

1797.

1798.



The system of sinking by dredging is generally to be preferred to the compressed air system, except where numerous obstacles, such as bowlders or imbedded trees, are met with.

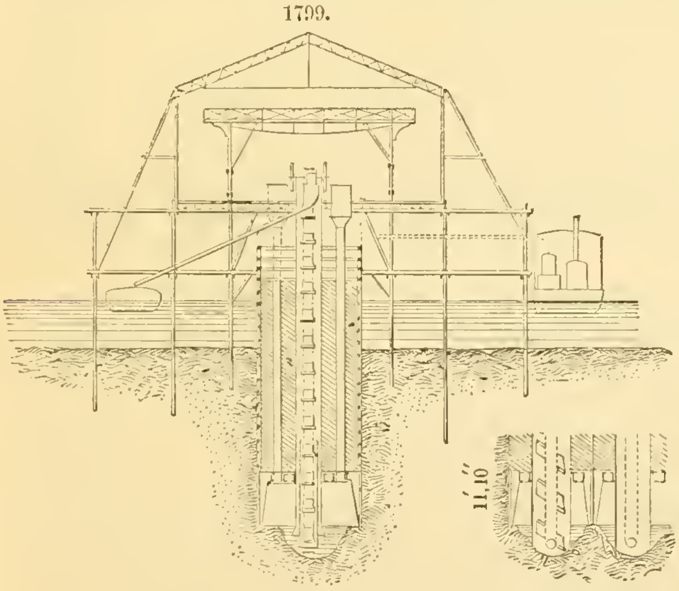
The friction between cylinders and the soil depends on the nature of the soil and the depth of sinking. For cast-iron sliding through gravel the coefficient of friction is between 2 and 3 tons on the square yard for small depths, and reaches 4 or 5 tons where the depth is between 20 and 30 feet. In certain adhesive soils it would be more. In sinking the brick and concrete cylinders in the silt of the Clyde it was found to amount to about 3$\frac{1}{2}$ tons per square yard.

The various details of the compressed air system are given in the descriptions of the works in which it has been employed. Theoretically, when the lower edge of the cylinder has reached a depth of $h$ feet below the surface of the water, the pressure required for driving the water out of the excavations is $\frac{3.14}{h}$ atmospheres; but frequently the intervention of the ground between the bottom of the river and the excavation enables the work to be carried on at a less pressure, as Mr. Brunel did at Saltash. A considerably greater pressure would be required if the water had to be forced from the excavation through the soil below the river-bed; but this is avoided by placing a pipe inside to convey away the water, and M. Triger has found that the lifting of the water was facilitated by the introduction of bubbles of air into the pipe at a certain height. Pressures of 2 or even up to 3 atmospheres do not injure healthy and sober men, and suit best men of a lymphatic temperament, but prove injurious to men who are plethoric or have heart-disease. It is advisable to avoid working in hot weather, and each workman should not work more than 4 hours per day, or more than 6

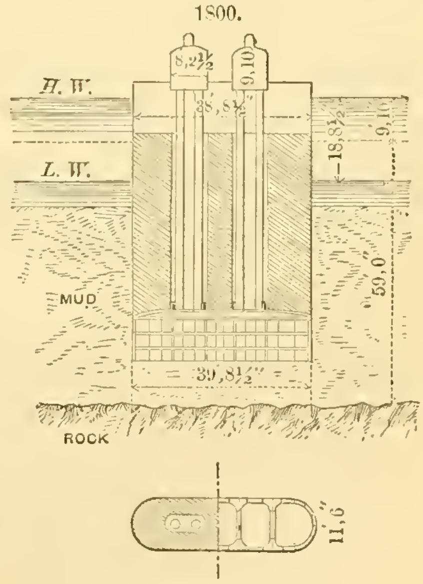
weeks consecutively. At Harlem, New York, however, workmen have remained 10 hours under a pressure of 50 feet, and even 80 feet of water. On the other hand, at St. Louis, under a pressure of little more than 3 atmospheres, several men were paralyzed or died, and the period of work was gradually reduced from 4 hours to 1 hour. From experiments on animals M. Bart has found that the accidents caused by a sudden removal of pressure are due to the escape of the excess of gas absorbed by the blood. Beyond 6 atmospheres any sudden return to the normal pressure is attended with danger; the usual rule now is to allow one minute per atmosphere. The cylinders subjected to pressure should be furnished with safety-valves, pressure-gauges, and alarm-whistles, as explosions occasionally occur. Iron rings from 6 to 13 feet in diameter are cast in one piece, and a caoutchouc washer is introduced at the joints between the rings; cylinders of larger diameter are cast in segments, and cylinders of smaller diameter than 6 feet are rarely used. The thickness is usually $1\frac{1}{4}$ inch, increased to $1\frac{1}{2}$ inch or $1\frac{7}{8}$ inch where exposed to blows, in conical joining lengths, and in the bottom length. When two cylinders have to be sunk close together, it is best to sink them alternately, as they tend to come together when sunk at the same time. At Macon, where there was only an interval of $3\frac{1}{2}$ feet between two cylinders, one of the cylinders was seen to rise suddenly as much as 6 feet when the other was forced down. Sometimes, where cylinders of small diameter have to be used, the excavations are extended beyond the cylinder at the bottom, and filled with concrete to give a greater bearing surface; this plan was adopted at Harlem bridge, New York, and by the late Mr. Cubitt, Vice-President Inst. C. E., at the Blackfriars railway bridge. Another way of accomplishing the same object is by enlarging the lower rings of the cylinder, and putting in a connecting conical length. Concrete deposited under compressed air appears to set quicker, and to increase somewhat in strength, provided it is deposited in thin layers allowing the excess of water to escape. At Szegedin this was effected by mixing very dry bricks with the concrete.

The foundations of the piers of the Kehl bridge were accomplished by the engineers, MM. Fleur Saint-Denis and Vuigner, by a combination of the principles of the compressed air process, the sinking of a pier by its own weight, the sinking by dredging, and the coffer-dam system. As the bed of the Rhine at Kehl consists of large masses of gravel liable to be disturbed to a depth of 55 feet below low-water level, it was deemed advisable to carry the foundations down about 70 feet below low water. For the two central piers the chamber of excavation was divided into three caissons, the length of each being 18 feet 4 inches, the width of the foundation. For the piers forming the abutments for the swing bridges there were four caissons, each 23 feet long, the breadth of all the caissons being 19 feet. The plate-iron forming the caissons was three-eighths of an inch thick at the top, and five-sixteenths of an inch thick at the sides, and strengthened by flanges and gussets. The top was strengthened by double T beams for supporting the weight of the masonry above. There were three shafts to each caisson, two being air-shafts, $3\frac{1}{4}$ feet in diameter, one being in use while the other was being lengthened or repaired; the other shaft in the centre was oval, open at the top, and dipping into the water in the foundations at the bottom, so that the water could rise in it to the level of the river. In this shaft a vertical dredger with buckets was always working, and the laborers had only to dig, to regulate the work, and remove any obstacles. The screw-jacks controlling

1799.




1800.



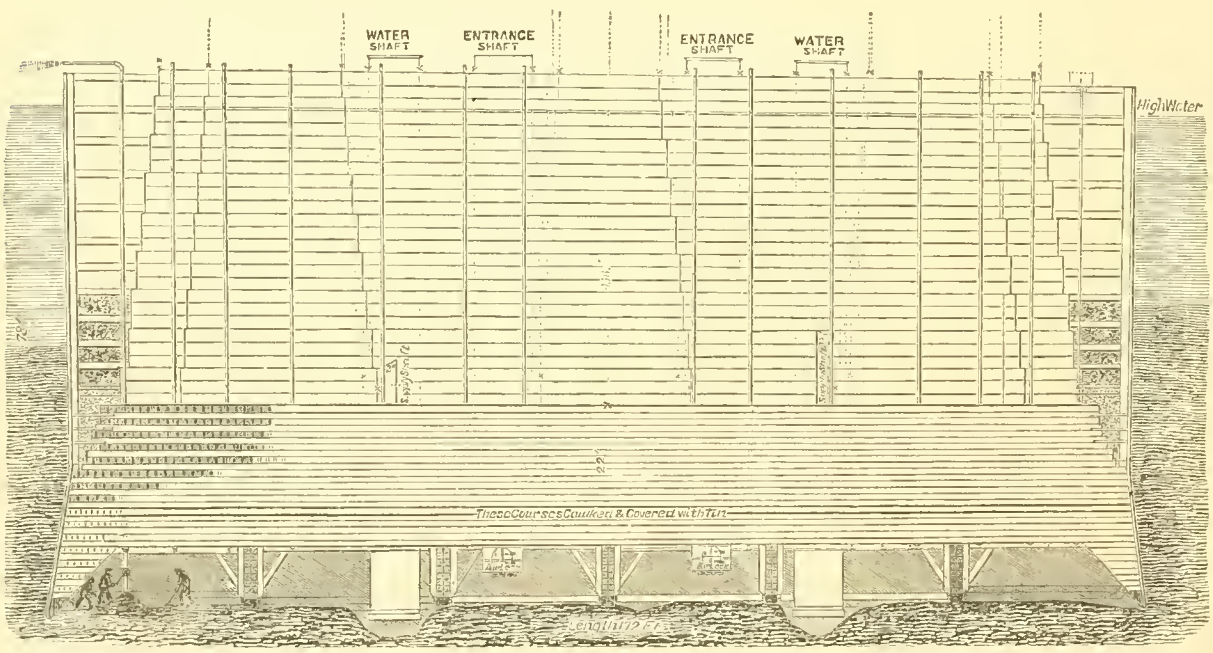

the rate of descent had a power of 15 tons, and were in four pairs. The wooden framing serving as a coffer-dam was erected above the chamber of excavation; it was useful at the commencement for getting below the water, but might subsequently have been dispensed with. It was also found by experience that the caissons were sunk better in one division than in several divisions, and doors of communication were accordingly made through the double partitions. The iron linings to the air-shafts were removed before the shaft was filled up. The shaft containing the dredger was at first made of iron, but afterward of brick for the sake of economy. The sinking occupied 68 days for one abutment and 32 days for the other, giving a daily rate of 1 foot 1 inch and 1 foot $8\frac{1}{2}$ inches respectively. The sinking of the caissons for the intermediate piers took 20 to 30 days, which gives a daily rate of 2 feet $7\frac{1}{2}$ inches (Fig. 1799).

For large works, where the load on the foundations is considerable, carrying down the foundations

to a hard bottom is much better than piling. The dredger used at Kehl cannot be regarded as universally applicable. Some soils are not suitable for dredging, and in other cases the small amount of excavation renders the addition of an extra shaft inexpedient, as, for instance, at Lorient. The chamber of excavation is almost invariably made of plate-iron, but, unlike those at Kehl, with the iron beams above the ceiling, instead of below, so that the filling in may be accomplished more easily. The cutting edge is always strengthened by additional plates. At Lorient the thickness was $2\frac{3}{16}$ inches, with several plates stepped back so as to form a sort of edge; the sides were about one-half of an inch thick at the bottom, and five-sixteenths of an inch at the top, and the roof was curved a little to increase its strength. There were two air-locks, each connected with two shafts, in which balanced skips went up and down, Fig. 1802. On the top of the bottom caisson a casing of sheet-iron, from three-sixteenths to one-eighth of an inch thick, and weighing about 15 tons, was erected in successive rings.

At the St. Louis bridge the foundations were carried to a greater depth than had ever been previously attained; and at the East River bridge compressed air was used in wooden caissons of large dimensions. The particulars of the St. Louis bridge have been given by Mr. Francis Fox, M. Inst. C. E. The hydraulic sand-pumping tube of Mr. Eads must only be recorded. The following details relate to the East River bridge: The Brooklyn pier was to be carried 50 feet and the New York pier 75 feet below high water. To provide against unequal sinking, owing to the variable nature of the soil, consisting of stiff clay mixed with blocks of trap rock, Mr. Roebling decided to place the bottom of the piers upon a thick platform of timber which formed the roof of the working chamber, Fig. 1801. The sides were also made of wood, as being easier than iron to launch and deposit on the exact site. The roof consisted of 5 tiers of beams, 1 foot deep, of yellow pine, placed one above the other and crossed, the beams being tightly connected by long bolts. The working chamber was 167 feet by 102 feet, and 10 feet clear height. The side walls had a V

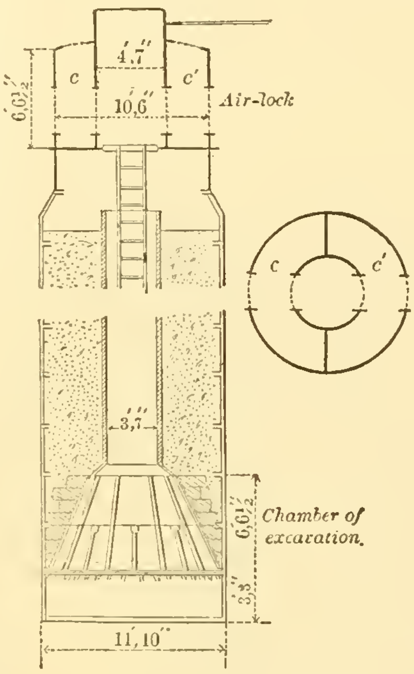
1801.



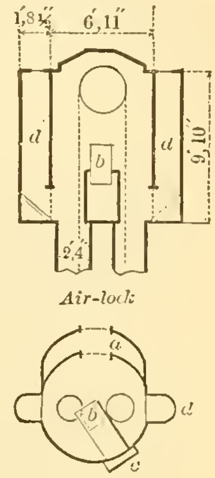

section, with a cast-iron edge covered with sheet-iron; the walls had a batter inside outward of 1 to 1, and 1 in 10 on the outside. Five transverse wooden partitions, 2 feet thick at the bottom, served to regulate the sinking. When the caisson had been put in place, 12 tiers of beams were added on the roof of the chamber of the Brooklyn pier, and 19 on that of the New York pier, so that the top rose above water, and the masonry could be built without a coffer-dam lining. The excavation, to the extent of 19,600 cubic yards, was performed in 5 months by Morris & Cumming's scoop dredger, working in two large shafts, dipping into the water at the bottom, and open above. When hard soil was met with these shafts were shut, and the excavation performed by manual labor under compressed air. In the New York caisson the total number of shafts was 9. The blocks of trap rock impeded the progress considerably; they had to be discovered by boring, and shifted or broken before the caisson reached them. When under 26 feet of water they could be blown up; this enabled the rate of progress, which had been 6 inches per week, to be doubled or trebled. When the caisson had reached a compact soil, it was possible to reduce the pressure to two-thirds of an atmosphere in excess of the normal pressure, and water had occasionally to be poured into the open shafts to maintain the proper water-level in them. By frequent renewal of the air, a supply was furnished for 120 men and for the lights; and the temperature was kept nearly constant throughout the year at 86° within the caisson, while in the open air it varied from 108° to 0°. As the load increased as the caisson went down, the roof of the Brooklyn caisson was eventually supported by 72 brick piers, so that the caisson might not become deeply imbedded in the event of a sudden escape of air. In the New York caisson two longitudinal partitions were added, which served the same purpose. In the silty sand which was frequently met with, a discharge-pipe, up which the sand was forced by compressed air, proved very useful, discharging a cubic yard in about two minutes. The New York caisson (170 feet by 102 feet) was sunk in 5 months; the earthwork removed amounted to 26,000 cubic yards.

At Bordeaux the air-lock was formed by fixing one circular plate at the top and another at the bottom of one of the rings of the cast-iron cylinder, so that it was unnecessary to remove it each time that an additional ring was added. To save loss of air, the air-lock should be opened very seldom, or made very small if required to be opened often. At Argenteuil the air-lock had an annular form, Fig. 1802, with two compartments *c c′*, each having an external and an internal door. One compartment was put in communication with the interior to be filled with the excavated material, while the other was being emptied by the outer door, so that the loss of air was diminished without any interruption to the work. Sometimes a double air-lock with one large and one small compartment is used; the large one being only opened to let gangs of workmen pass, and the small one just big enough to admit a skip and to contain a little crane for moving it. By having a small air-lock opened frequently, any sudden alterations in pressure are diminished. A more complete arrangement was adopted at Nantes, Fig. 1803. There a sheet-iron cylinder was placed on the top of the double shaft in which the skips worked, having at one side a crescent-shaped chamber, *a*, serving to pass four men, and also on either side two concrete receivers, *d d′*, having doors above and below. There was also a shoot below for turning the concrete into the foundations, and a box, *b c*, holding a little wagon which emerges at *c* after having been filled from an upper door *b*.

1802.




1803.

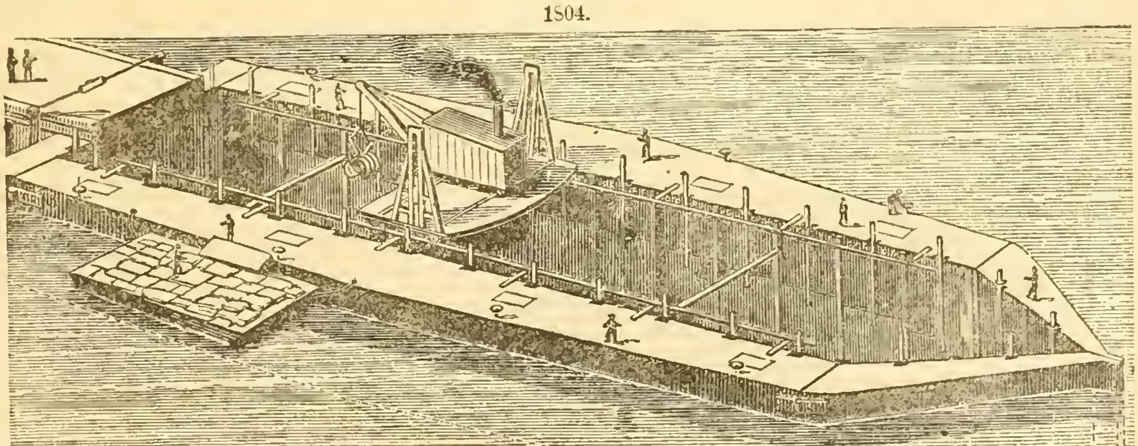



M. Desnoyers gives the following recommendations with regard to the choice of methods of constructing foundations:

1. In still water, to construct the foundations by means of pumping for depths under 20 feet. In greater depths, to construct ordinary works on piles if the ground is firm or has been consolidated by loading it with earth; otherwise to employ pumping, and if a permeable stratum is met with to build on it with a broad base. For important works, if the soil is water-tight, it is advisable to adopt the method of pumping inside a framing, carrying down the foundations to greater depths than 33 feet by the well-sinking method. If the soil, however, is permeable, dredging and concrete deposited under water must be resorted to, compressed air being employed for depths greater than 33 feet.

2. In mid-stream, compressed air must be resorted to for foundations more than 33 feet below water. In less depths the foundations of ordinary works are put in by means of dams or water-tight frames, if the nature of the silt admits of pumping out the water; but if the silt is permeable, a mass of concrete is poured into the site inclosed by sheeting. When, however, an important work has to be executed, it is desirable to use pumps sufficient to overcome the infiltrations. If a permeable and easily-dredged stratum lies between the hard bottom and the silt, the method of a water-tight casing, with a dam at the bottom, should be adopted. To complete these recommendations, open cylindrical foundations must be included. These may be resorted to, instead of compressed

1804.



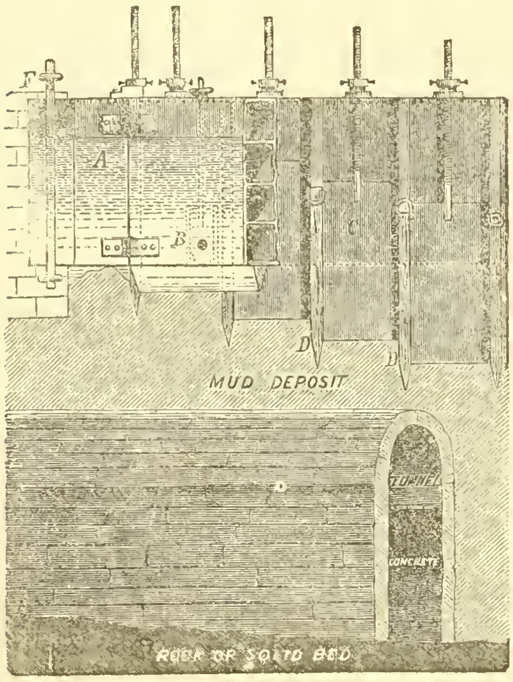
air, when the soil is readily dredged or water-tight enough to allow of pumping, and also frequently in the place of piles or the well-sinking method. The compressed air system is essentially a last resource, applicable to a bed exposed to scour, and also either difficult to dredge or with bowlders or other obstacles imbedded in it.

*Portable Coffer-Dam.*—Walsh's portable coffer-dam is formed of water-tight compartments, which, when the apparatus is to be towed from one point to another, are filled with air only; but when it is desired to locate the dam, water is admitted into the sections, causing the entire structure to sink

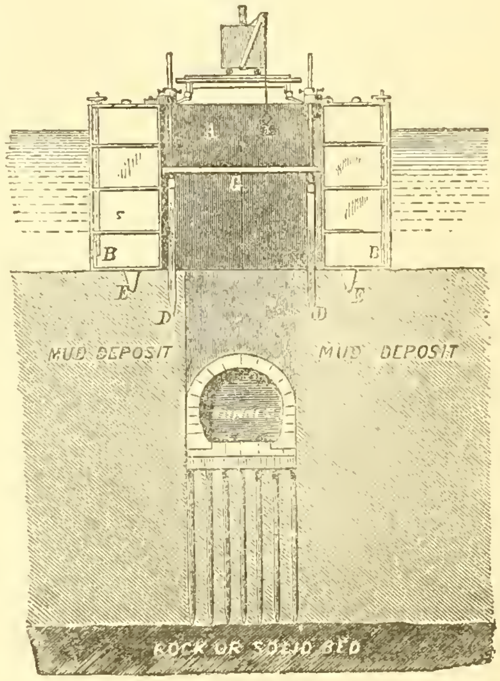
and rest on the bottom. Fig. 1804 represents the dam in position for the construction of a pier, the dotted lines indicating the depth of the structure. The forward portion is shaped somewhat like the bow of a vessel, by connecting together two hinged gates, formed of metal, and each constituting a compartment similar to those into which the body of the dam is divided. The rear portion of the structure is provided with similar doors, made so as to secure and fit tightly against the sides of the pier-end. The manner in which the body is constructed in sections is shown in Figs. 1805 and 1806. In the latter engraving the rear gates are represented at *A*; and at *B B* are the valves which admit water to the compartments to sink the same. At *C*, Fig. 1805, are the plate-piles, which are raised or lowered by the screws attached to their upper portions. *D D* are the holding-piles, sliding upon T irons. Under the body is a keel *E*. Over the open middle portion is a track to support a dredge, and pile-drivers and clamping-bars *G* bind the sides together.

In operation, the sheet and square piles are first raised so that their lower edges and ends will be above the bottom of the sections. The latter being emptied, the dam is floated to the desired point and sunk. The square piles are then forced into the earth to form a solid bearing, the sheet piles

1805.




1806.




being driven in until bed-rock is reached. The water in the middle space is then pumped out, and building therein is begun. To extend the masonry farther out into the water, the piles are raised and the dam floated and towed ahead until the rear gates once more embrace the extremity of the structure. Figs. 1805 and 1806 also show two methods of building a tunnel by the aid of this apparatus. In Fig. 1805 piles are driven down until their ends meet hardpan, and above them the masonry of the tunnel is built, as shown, concrete being placed over all. In Fig. 1806 the digging is carried down to bed-rock, and the masonry is built therefrom upward. The lower part is filled with concrete up to the level of the tunnel floor.

*Works for Reference.*—See the text-books on civil engineering by Rankine (11th ed., London, 1876), Mahan (2d ed., revised by Wood, New York, 1877), and Wheeler (New York, 1877).

FOUNDING. See CASTING.

FOURDRINIER MACHINE. See PAPER-MAKING.

FRAISING MACHINE. See MILLING MACHINE.

FRAMING. See CARPENTRY.

FRICTION. Friction is the resistance occasioned to the motion of a body when pressed upon the surface of another body which does not partake of its motion. Under these circumstances, the surfaces in contact have a certain tendency to adhere. Not being perfectly smooth, the imperceptible asperities which may be supposed to exist on all surfaces, however highly polished, become to some extent interlocked, and in consequence a certain amount of force is requisite to overcome the mutual resistance to motion of the two surfaces, and to maintain the sliding motion even when it has been produced. By increasing the pressure, the resistance to motion is increased also; and on the other hand, by rendering the surfaces more smooth, and by lubrication, its amount is greatly diminished, but can never be entirely nullified.

Friction ought not strictly to be called a *force*, unless that term be in this case taken in a negative sense. The tendency of force, in the rigid meaning of the word, is to produce motion, whereas the tendency of friction is to destroy motion. An active force may indeed oppose motion in one direction, but only in virtue of a tendency to produce motion in the opposite direction; the peculiar characteristic of friction, on the other hand, is that it tends to destroy motion in every direction. It is essentially a passive resistance, a negative force, produced by pressure, to which it bears such relation that its amount may be measured by the same unit and enunciated in the same terms.

Nor is the measure of the friction between two surfaces in contact properly the amount of force necessary to produce motion, but the amount of pressure necessary to balance the friction, and bring

the body to a state of indifference to rest or motion. To understand this, let us suppose that a heavy hemispherical body rests with its flat surface upon a horizontal plane, and that the plane and the body are *perfectly smooth:* on this supposition there would be no friction, and the smallest possible force would put the body in motion. This condition being remarked, let us suppose that the surfaces in contact are of the ordinary kind, and that a weight of 10 lbs. attached to the movable body, and made to act in the direction of the plane, is found to induce the same state of indifference to rest and motion as in the assumed case of no friction; we then conclude that 10 lbs. is the measure of the friction. As it is not always easy to determine when this condition is induced, it is better to regard the weight as an active force, which may by addition be made more and more intense, till motion of the body is actually induced. For the sake of convenience we may also speak of friction as a force, and oppose it to other force: this can induce no erroneous conclusion.

Friction being then considered a *passive* force, its effect is the result of having other force to resist. If the measure of the friction of a body upon a plane be 10 lbs., and if an increasing force of 1, 2, 3 lbs., and so on, be applied, the friction increases with the force till the limit is reached; motion then ensues by the addition of any fraction of weight to the 10 lbs. The *force* of friction, although tending to prevent or destroy motion, may also be conceived to act, like other force, in a direction opposite to that in which the balancing force acts; that is, in the language of mechanics, if the force $P$, applied to balance the friction $F$, act in the direction $A\,B$, the friction $F$ acts in the direction $B\,A$. If then the body placed upon the horizontal plane, as supposed, be capable of motion in the two directions $A\,B$ and $B\,A$, the body will remain at rest when acted upon by any force up to 10 lbs. in either of the directions. If, therefore, we distinguish the forces acting in opposite directions by the positive and negative symbols + and —, then the limits of equilibrium will be expressed by $P = \pm$ 10 lbs., according to the usual mode of representing an equilibrium of forces.

$A$ ———————————— $B$

What is here stated in reference to a heavy body placed upon a horizontal plane, is equally true of the rubbing parts of every machine: the pressure upon the journals producing resistance to motion, that is, friction, the equilibrium will subsist between certain limits, and it is only by transgression of those limits on one side that the equilibrium is destroyed and motion established. To determine accurately those limits in machines is one of the most important problems in mechanics; and the experiments conducted by the French Academy have furnished data that have long been recognized as standard. From the results of these experiments certain rules have been deduced that have been regarded as invariable laws, but which have been brought in question by more recent investigations. The laws referred to are given below, together with a summary of the results on which they are based, and references to the later experiments by other investigators.

Law I.—*The friction bears to the pressure upon the surfaces in contact a ratio which is constant for the same materials with the same condition of surfaces.*

To express this somewhat more familiarly: If the surface of one body be pressed upon that of another with a certain force, and if that force be doubled, the friction will be doubled; and if the force pressing them together be tripled, the friction will be tripled; and so on. Thus, if a piece of cast-iron weighing 100 lbs. be laid with its plane surface upon a larger surface of brass, level, and it be found that a certain weight made to act in the direction of the supporting plane is just sufficient to induce in the mass of iron a state of indifference to rest or motion, that weight is the measure of the friction between the two surfaces; and if these be well polished and clean, and without lubricant of any kind, the weight which it will be necessary to apply will be 14.7 lbs. If now we place a weight of 100 lbs. upon the mass of cast-iron, making the gross pressure upon the surfaces in contact 200 lbs., the weight necessary to balance the friction will be increased in the same ratio; that is, $F = 14.7 \text{ lbs.} \times 2 = 29.4$ lbs. Another weight of 100 lbs., placed on the first, making the pressure 300 lbs., will increase the measure of friction to $14.7 \text{ lbs.} \times 3 = 44.1$ lbs. And so on for every increment of pressure as expressed by the law.

If now we divide the weight which balances the friction by the weight which measures the pressure upon the surfaces, we obtain a ratio which is manifestly constant, since the pressures upon the surfaces and the weights balancing the friction, corresponding to those pressures, are respectively multiples throughout of the first units 100 lbs. and 14.7 lbs. Thus we have

$$\frac{14.7 \text{ lbs.}}{100 \text{ lbs.}} = \frac{29.4 \text{ lbs.}}{200 \text{ lbs.}} = \frac{44.1 \text{ lbs.}}{300 \text{ lbs.}} = .147$$

From this then it appears that, knowing the measure of the friction for a given unit of pressure upon the surfaces in contact, these remaining constant in kind and condition, the measure of the friction answering to any other pressure may be deduced. In the case assumed we have a common ratio of .147 as the measure of the friction between the surfaces in contact; this ratio therefore being known, together with the pressure in the particular case, the measure of the friction for that case will also be known. Putting $P =$ the pressure upon the rubbing surfaces, $F =$ the measure of the friction, and $f = \frac{F}{P}$; then we have $F = f \times P$.

In this formula the ratio $f$ of the friction to the pressure is termed the *coefficient of friction.* Its value, as already announced, is constant for the same materials and condition of the surfaces in contact, but varies as these vary. Thus in the particular case taken, the value is .147; but if the rubbing surfaces be *unctuous,* it is reduced to .132; that is, by repetition of the experiments described above, with this new condition of surfaces, we should find

$$\left.\begin{aligned} F &= f \times P = .132 \times 100 \text{ lbs.} = 13.2 \text{ lbs.} \\ F &= f \times P = .132 \times 200 \text{ lbs.} = 26.4 \text{ lbs.} \\ F &= f \times P = .132 \times 300 \text{ lbs.} = 39.6 \text{ lbs.} \end{aligned}\right\} \text{measures of the friction.}$$

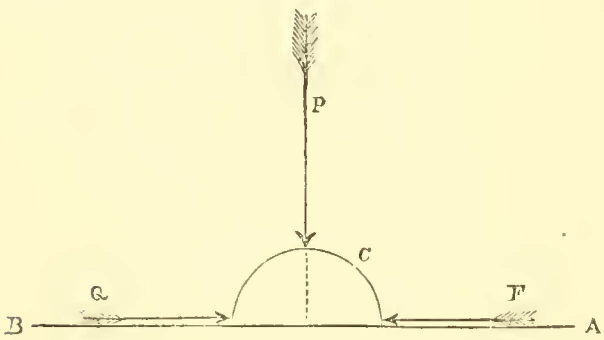
If a cast-iron plate be substituted for the brass plate used as the supporting surface, and the surfaces be first well polished, clean, and dry, next wetted with water, and lastly be freely lubricated with hogs' lard, we have the three values $f = .152$, $f = .314$, $f = .07$, answering to these conditions; hence, taking $P$ as before, we have, by substitution in the formula $F = f \times P$, the following results:

| | Surfaces wet. | Surfaces dry. | Surfaces lubricated. |
|---|---|---|---|
| For 100 lbs. .............. | $F = 15.2$ lbs. | $F = 31.4$ lbs. | $F = 7$ lbs. |
| " 200 lbs. .............. | $F = 30.4$ lbs. | $F = 62.8$ lbs. | $F = 14$ lbs. |
| " 300 lbs. .............. | $F = 45.6$ lbs. | $F = 93.2$ lbs. | $F = 21$ lbs. |

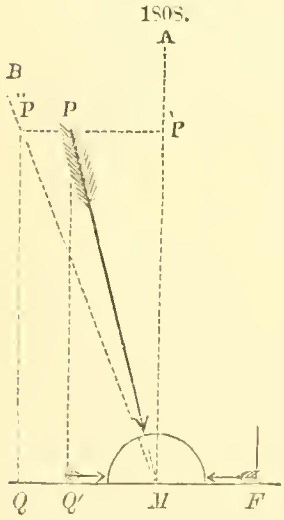
The determination of $f$, that is, of the coefficient of friction, for different kinds of materials, and also for different states of their surfaces in contact, is manifestly the business of experiment. There is no *a priori* rule by which it can be arrived at in the present state of our knowledge of the physical properties of bodies.

There is another mode of considering the subject here discussed, which has its expression likewise in the subjoined table, and which it becomes us therefore to explain. Let us suppose the arrangement as in the experiments described, and that $A\,B$, Fig. 1807, is the supporting surface, and $C$ the mass of cast-iron resting upon it. Again, let the pressure of the mass acting perpendicularly to the surfaces in contact be denoted by $P$, and let the force $Q$, parallel to the surfaces, be applied to slide the body toward $A$. Then, since the forces $P$ and $Q$ act in directions perpendicular to one another, they manifestly cannot counteract one another; consequently, were there no third force $F$ opposed to $Q$, the system would be unbalanced, and there would obviously be motion of the mass $C$ in the direction of the second force. The third force $F$ is the friction, and so long as the force $Q$ does not exceed its limit, the system must remain stable. This being understood, let us suppose that the force $P$, Figs. 1808 and 1809, instead of having its direction perpendicular to the surfaces in contact, is impressed obliquely; if then the parallelogram of forces $P'\,Q$ be completed, the force $P$, represented by the line $P\,M$, is equivalent to two others represented by $P'\,M$, by which the surfaces are pressed together, and $Q\,M$, which tends to give motion to the body in a direction parallel to the surfaces. Now the actual friction $F$ of the surfaces must be a certain fraction of $P\,M$; let it be $M\,Q' = M\,F$, and complete the parallelogram $P'\,Q'$, and draw its diagonal $P''\,M$. Since then $M\,Q'$ represents the friction of the body upon the plane, that is, the resistance called into action by the force $P\,M$, and since $Q\,M$ represents the whole tendency of $P\,M$ to produce motion of the body, it follows that the body will move or not according as $Q\,M$ is greater or less than $Q'\,M$, that is, as $P\,P'$ is greater or less than $P''\,P'$, or as the angle $P\,M\,A$ is greater or less than the angle $B\,M\,A$. These conditions are shown in the diagrams: in the first there would be motion induced by the preponderance of force $Q\,Q'$; in the second, the friction $F = M\,Q'$ being greater than $Q\,M$, the system would remain at rest.

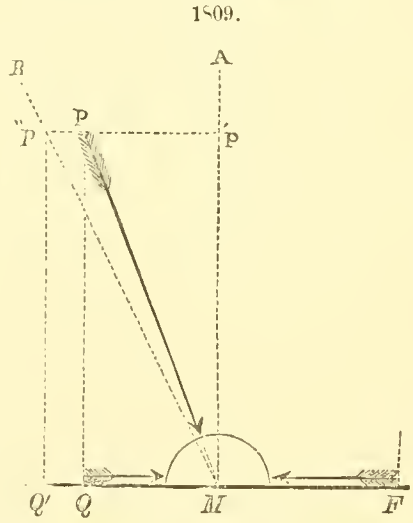
1807.




1808.




1809.




The angle $B\,M\,A$ is termed the *limiting angle of resistance*, or more shortly the *angle of friction*. Its tangent is the fraction $\frac{P'\,P''}{P'\,M} = \frac{M\,Q'}{P'\,M}$, which is the *coefficient of friction*. The angle is manifestly the same for surfaces of the same nature, whatever be the actual amount of the impressed force $P$, but is different for different surfaces.

From this, then, it appears that the force impressed upon the surface of a solid body, at rest, by the intervention of another solid body, will be destroyed, whatever be its direction, provided only the angle which the direction makes with the perpendicular to the surface do not exceed the angle of friction of that surface; and that this is true, however *great* the force may be. Also, that if the direction of the force lie without this angle, it cannot be sustained by the resistance of the surfaces in contact; and that this is true, however *small* the force may be.

Law II.—*The measure of friction is independent of the extent of surface, the pressure and the condition and character of the surfaces remaining the same.*

Experiments on sliding friction, made with different materials and with pressures increasing up to

the limits of abrasion, show that the above laws are not universally true, and that the coefficient of friction does not vary with the pressure and independently of the surface, for all pressures. A record of these experiments was published in the "Philosophical Transactions" for 1829. Even before the pressure producing abrasion is reached, it may be so intense as to force out the lubricant, and thus entirely change the conditions. A familiar example of increase of surface with supposed advantage is to be found in the enlargement of car-axle journals on American railroads, with the result, as is generally supposed, of reducing the frictional resistance, on account of the more effectual lubrication that has been possible since the change.

LAW III.—*The friction is entirely independent of the velocity of continuous motion.*

It can safely be asserted that this third law, which is to be found in nearly all modern text-books on applied mechanics, has been completely disproved by the experiments of Hirn, Bochet, and Kimball, which are detailed in the *Bulletin de la Société Industrielle de Mulhouse*, 1854, *Annales des Mines*, 1858, 1861, and *The American Journal of Science and Arts*, March, 1876, and May, 1877, respectively. Unfortunately, in overthrowing Morin's law, the experimenters have not furnished a substitute. Hirn, who used very light pressures and moderate velocities, announced, as the result of his experiments, that the coefficient of friction increased with increase of velocity. Bochet's experiments were made by sliding the wheels of loaded cars on rails, so that the pressures were very large; and the deduction from his investigations was that the coefficient of friction decreased as the velocity was increased. Prof. Kimball's experiments, however, which have been conducted with a wide range of pressures and velocities, render it probable that each of the laws announced by the former experimenters is correct for the circumstances under which the trials were made. To use the last investigator's own language:

"Morin experimented under conditions which gave him a coefficient very near the maximum, and thus his results are approximately constant. Bochet experimented with railway trains; his conditions were high speeds, hard rubbing surfaces, and great intensity of pressure. All these circumstances are favorable to the result he obtained, namely, a coefficient decreasing as the velocity increases. Hirn, on the other hand, employed very light pressures—less than two pounds on a square inch—and kept his rubbing surfaces so thoroughly lubricated, that the friction was between oil and oil instead of two metal surfaces; his speeds were not very great. These conditions are precisely the ones I have found favorable to the results he reached—a coefficient increasing as the velocity increases.

"The result of my experiments would indicate that the following is the true law, within the range of my experience: The coefficient of friction at very low velocities is small; it increases rapidly at first, then more gradually as the velocity increases, until at a certain rate, which depends upon the nature of the surfaces in contact and the intensity of the pressure, a maximum coefficient is reached. As the velocity continues to increase beyond this point, the coefficient decreases. An increase in the intensity of the pressure (the number of pounds on a square inch) changes the position of the maximum coefficient, and makes it correspond to a smaller velocity. The more yielding the materials between which the friction occurs, the higher is the velocity at which the maximum coefficient is found. Heating the rubbing surfaces changes the position of the maximum coefficient to a higher velocity, since by heat the two bodies are made softer, and are caused to yield to pressure with greater ease. For a considerable range of velocities in the vicinity of the maximum coefficient, the coefficient is sensibly constant."

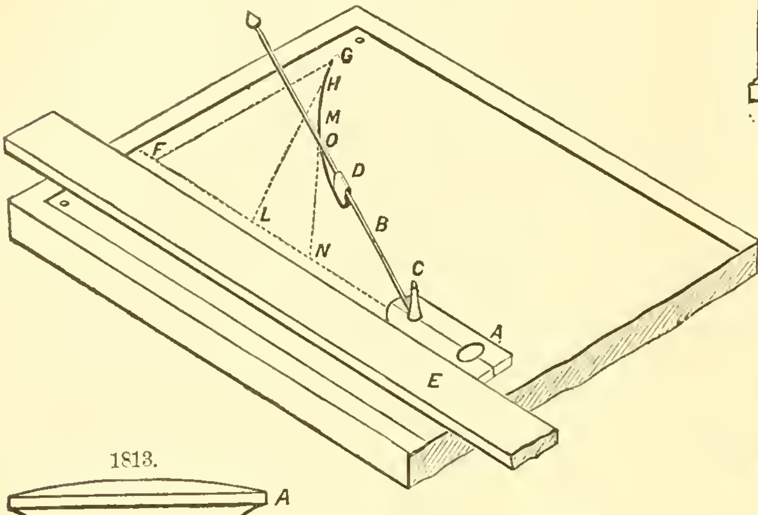
It seems evident from the foregoing that researches on the laws of friction must be greatly extended before constants that may be accepted without question can be deduced; and the reader will perceive that the tables which follow, long received as standard authority, contain results that are not universally true, as already explained.

In estimating the friction of pivots, the coefficient of friction is that of sliding friction multiplied by a certain constant, depending upon the form of the pivots. The following formulæ from "Des Ingenieur's Taschenbuch," Berlin, 1875, show how this constant is calculated. If $f$ is the coefficient of sliding friction, it may be assumed also as the coefficient of pivot friction, acting with an arm of $\frac{2}{3}r$ for a flat pivot with radius $r$; $\frac{2}{3} \times \frac{R^3 - r^3}{R^2 - r^2}$ for a pivot with an annular base, $R$ and $r$ being the internal and external radii respectively; $\frac{\pi}{2} \times r$ for a pivot with a hemispherical base, of radius $r$; $\frac{2}{3} \times \frac{R^3 - r^3}{R^2 - r^2} \times \frac{1}{\sin. a}$ for a pivot in the form of a frustum of a cone, not bearing on the bottom, $R$ and $r$ being the two extreme radii in the bearing, and $a$ the angle of inclination; $\frac{2}{3} \times \frac{R}{\sin. a}$ for a conical pivot, with radius $R$, $a$ being the angle of inclination.

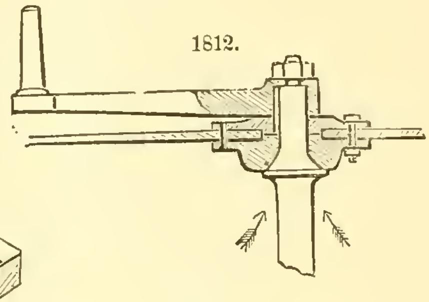
If a conical pivot, Fig. 1810, of some soft material, such as chalk, is revolved in a bearing made of the same material, the bearing having clearance at the bottom as indicated, it will be found that the pivot will gradually wear away, until its section is of the form shown by the dotted lines, making a curve known as the tractrix, and frequently called Schiele's anti-friction curve. A peculiar property of this curve is that tangents drawn from any points to the axis will all be of the same length, so that a pivot having this section will be pressed equally over its whole bearing surface, thus distributing the wear. The curve is known as Schiele's, from the fact that Christian Schiele took out a patent in 1850 for a method of drawing the curve mechanically, as shown in Fig. 1811. A somewhat similar method had, however, been described by Prof. John Leslie, in "Geometrical Analysis, and Geometry of Curve Lines," Edinburgh, 1821. In Schiele's instrument, $A$ is a wooden

slide, to which the rod $B$ is jointed by a pin $C$. A slide $D$ on the rod carries a drawing pen, and $E$ is a ruler which acts as a guide for the slide $A$. To draw the curve, the slide $A$ is placed so that the

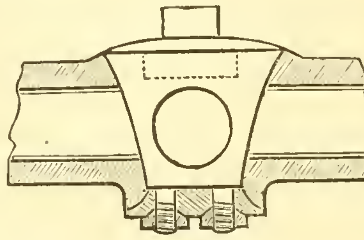
1811.



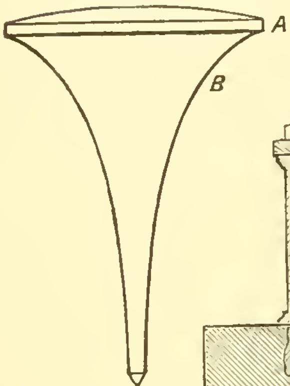

1812.



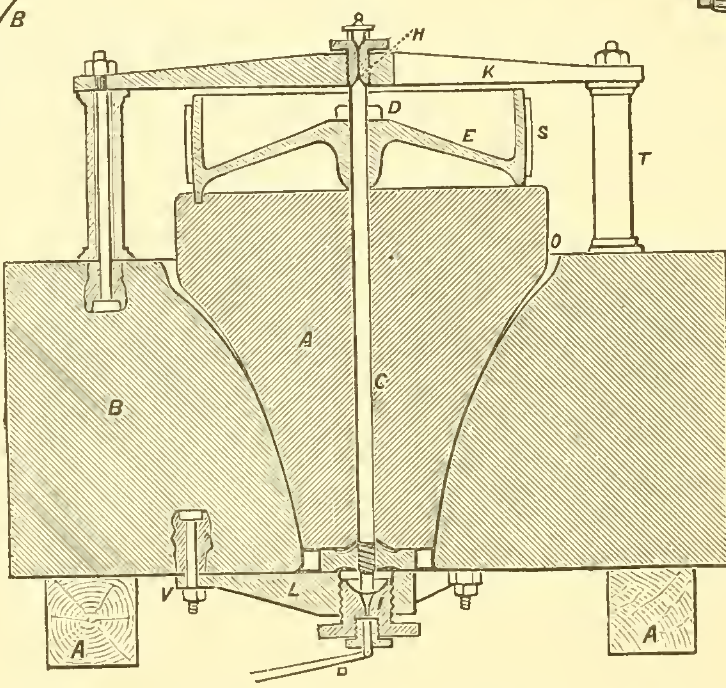
1814.



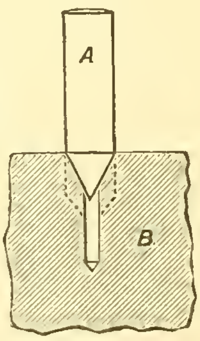
1813.




1815.




1810.

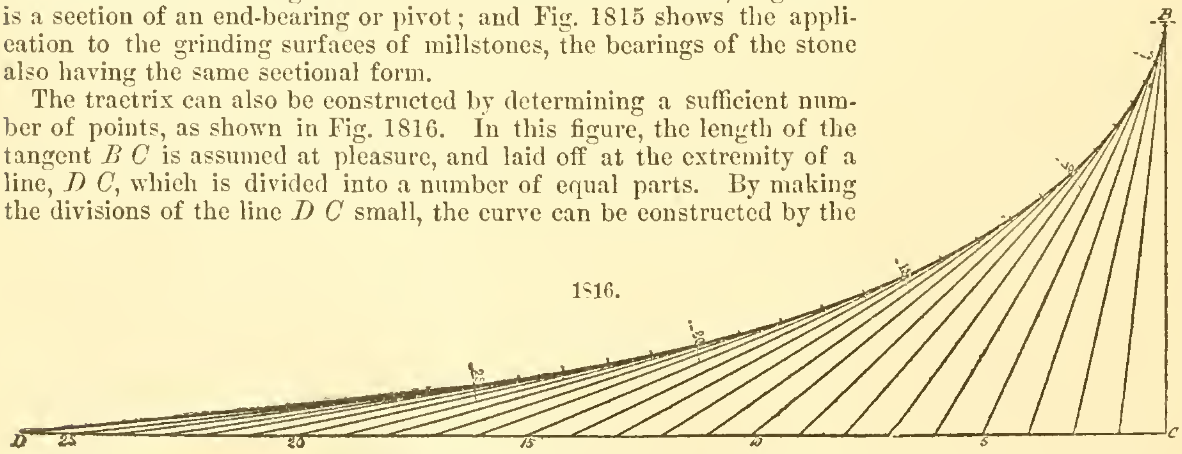



rod occupies the position $F\,G$, and the slide $D$ is then adjusted to the length of tangent required. By moving the slide $A$ along the ruler, the pen in the slide $D$ traces the required curve $G\,H\,M\,O$.

Some applications of the curve are shown in the accompanying figures. Fig. 1812 illustrates a substitute for the stuffing-box of a locomotive throttle-valve; Fig. 1813 is a section of an end-bearing or pivot; and Fig. 1815 shows the application to the grinding surfaces of millstones, the bearings of the stone also having the same sectional form.

The tractrix can also be constructed by determining a sufficient number of points, as shown in Fig. 1816. In this figure, the length of the tangent $B\,C$ is assumed at pleasure, and laid off at the extremity of a line, $D\,C$, which is divided into a number of equal parts. By making the divisions of the line $D\,C$ small, the curve can be constructed by the

1816.




tangents, as shown, drawing from each point of division a straight line to the point previously determined, and laying off on it the length of the tangent—proceeding in regular order from the starting-point, which is fixed by the length of the perpendicular $C\,B$. By the aid of the numbers on base-line and curve, the successive steps of the construction can readily be traced by the reader. If $t$ is

*Summary of M. Morin's Experiments on the Friction of Plane Surfaces.*

| Sliding surface. | Surface at rest. | State of the surfaces. | | Friction of motion. Co-efficient of friction. | Friction of motion. Limiting angle of resistance. | Friction of quiescence. Co-efficient of friction. | Friction of quiescence. Limiting angle of resistance. |
|---|---|---|---|---|---|---|---|
| Oak ........ | Oak ....... | Direction of fibres parallel to the motion............... | Without lubrication....... | 0·478 | 25°33′ | 0·625 | 32° 1′ |
| | | | Lubricated with tallow .. | 0·975 | .... | 0·160 | .... |
| | | | Lubricated with lard .... | 0·067 | .... | .... | .... |
| do......... | do......... | Fibres of the moving surface perpendicular to the motion. | Without lubrication....... | 0·324 | 17 58 | 0·540 | 28 23 |
| | | | Unctuous................. | 0·143 | 8 9 | 0·314 | 17 26 |
| | | | Lubricated with tallow .. | 0·083 | .... | 0·254 | .... |
| | | | Lubricated with lard .... | 0·072 | .... | .... | .... |
| | | | Lubricated with water... | 0·250 | .... | .... | .... |
| do......... | do......... | Fibres of both surfaces perpendicular to the direction of the motion ................. | Without lubrication ..... | 0·336 | 18 35 | .... | .... |
| do......... | do......... | Fibres of the moving surface perpendicular to the surface of contact, and those of the quiescent surface parallel to the motion ................. | Without lubrication ..... | 0·192 | 10 52 | 0·271 | 15 10 |
| do......... | do......... | Fibres of both surfaces perpendicular to the surface of contact, or the pieces end to end. | Without lubrication..... | .... | .... | 0·43 | 23 17 |
| Oak ........ | Elm ........ | Fibres parallel to the motion. | Without lubrication....... | 0·246 | 13 50 | 0·376 | 20 37 |
| | | | Unctuous ................ | 0·136 | 7 45 | .... | .... |
| | | | Lubricated with dry soap | 0·136 | .... | .... | .... |
| | | | Lubricated with tallow .. | 0·073 | .... | 0·178 | .... |
| | | | Lubricated with lard .... | 0·066 | .... | .... | .... |
| Elm ........ | Oak ....... | Fibres parallel to the motion.. | Without lubrication....... | 0·432 | 23 22 | 0·694 | 34 46 |
| | | | Unctuous................. | 0·119 | 6 48 | 0·420 | 22 47 |
| | | | Lubricated with dry soap | 0·137 | .... | 0·411 | .... |
| | | | Lubricated with tallow .. | 0·070 | .... | 0·142 | .... |
| | | | Lubricated with lard .... | 0·060 | .... | .... | .... |
| | | Fibres of the moving surface perpendicular to the motion.. | Without lubrication...... | 0·450 | 24 16 | 0·570 | 29 41 |
| Beech ...... | Oak ....... | Fibres of both surfaces parallel to the motion............. | Without lubrication....... | 0·360 | 19 48 | 0·530 | 27 56 |
| | | | Unctuous................. | 0·330 | 18 16 | .... | .... |
| | | | Lubricated with tallow.... | 0·550 | .... | .... | .... |
| Ash and Sorrel wood ... Fir .......... Pear-tree .... Wrought-iron Cast-iron .... | Oak ....... | Fibres of both surfaces parallel to the motion............. | Without lubrication....... | 0·400 | 21 49 | 0·570 | 29 41 |
| | | | ....do........do.. ........ | 0·355 | 19 33 | 0·520 | 27 29 |
| | | | ....do........do.......... | 0·370 | 20 19 | 0·440 | 23 45 |
| | | | ....do........do.......... | 0·619 | 31 47 | 0·619 | 31 47 |
| | | | Lubricated with dry soap | 0·214 | .... | .... | .... |
| | | | Lubricated with tallow .. | 0·085 | .... | 0·108 | .... |
| Oak ........ Elm ........ Wrought-iron | Wrought-iron Elm ........ do.......... | .....do............do..... | Tallow ................... | 0·098 | .... | .... | .... |
| | | | Greased and saturated with water ................... | 0·256 | .... | 0·649 | .... |
| | | | Without lubrication....... | 0·252 | 14 9 | .... | .... |
| | | | Unctuous................. | 0·138 | 7 52 | .... | .... |
| | | | Lubricated with tallow .. | 0·078 | .... | .... | .... |
| | | | Lubricated with lard .... | 0·076 | .... | .... | .... |
| | | | Lubricated with olive oil. | 0·055 | .... | .... | .... |
| Cast-iron .... | Oak ........ | .......do...........do..... | Without lubrication....... | 0·490 | 26 7 | .... | .... |
| | | | Unctuous................. | 0·107 | 6 7 | 0·100 | 5 43 |
| | | | Lubricated with dry soap | 0·189 | .... | .... | .... |
| | | | Lubricated with tallow .. | 0·078 | ... | 0·100 | .... |
| | | | Lubricated with lard or olive oil | 0·075 | .... | 0·100 | .... |
| | | | Greased and saturated with water................... | 0·218 | .... | 0·646 | .... |
| Oak ........ | Cast-iron ... | Fibres of the wood parallel to the motion. | Lubricated with tallow... | 0·80 | .... | .... | .... |
| | | do........do. perpedicular to the motion. | Without lubrication...... | 0·372 | 20 25 | .... | .... |
| Cast-iron .... | Elm ... .... | do........do. parallel to the motion. | ....do........do.......... | 0·195 | 11 3 | .... | .... |
| | | | Surface unctuous with tallow | 0·125 | 7 8 | .... | .... |
| | | | Surface unctuous with lard | 0·137 | 7 49 | .... | .... |
| | | | Lubricated with tallow .. | 0·077 | .... | .... | .... |
| | | | Lubricated with lard .... | 0·091 | .... | .... | .... |
| | | | Lubricated with olive oil. | 0·061 | .... | .... | .... |
| Elm ........ Hornbeam ... Pear-tree .... Copper ...... | Cast-iron .... do. .... do. .... Oak ........ | .....do............do..... | Surfaces unctuous......... | 0·135 | 7 42 | 0·098 | 5 36 |
| | | | do. lubricated with tallow | 0·066 | .... | .... | .... |
| | | | Without lubrication....... | 0·394 | 21 31 | .... | .... |
| | | | ....do........do.......... | 0·436 | 23 34 | .... | .... |
| | | | ....do........do.......... | 0·617 | 31 41 | 0·617 | 31 41 |
| | | | Surfaces unctuous......... | 0·100 | 5 43 | .... | .... |
| | | | Lubricated with tallow.... | 0·069 | .... | 0·100 | .... |
| Wrought-iron | Wrought-iron | Fibres of both surfaces parallel to the motion....... | Without lubrication....... | 0·138 | 7 52 | 0·137 | 7 49 |
| | | | Surfaces unctuous......... | 0·177 | 10 3 | .... | .... |
| | | | Lubricated with tallow .. | 0·082 | .... | .... | .... |
| | | | Lubricated with lard .... | 0·081 | .... | .... | .... |
| | | | Lubricated with olive oil. | 0·070 | .... | 0·115 | .. |
| Wrought-iron | Cast-iron .... | .......do....... ....do..... | Without lubrication....... | 0·194 | 10 59 | 0·194 | 10 59 |
| | | | Surfaces unctuous......... | .... | .... | 0·118 | 6 44 |
| | | | Lubricated with tallow .. | 0·103 | .... | .... | .... |
| | | | Lubricated with lard .... | 0·076 | .... | .... | .... |
| | | | Lubricated with olive oil. | 0·066 | .... | 0·100 | 5 43 |

*Summary of M. Morin's Experiments on the Friction of Plane Surfaces (continued).*

| SLIDING SURFACE. | SURFACE AT REST. | STATE OF THE SURFACES. | | Friction of motion. Co-efficient of friction. | Friction of motion. Limiting angle of resistance. | Friction of quiescence. Co-efficient of friction. | Friction of quiescence. Limiting angle of resistance. |
|---|---|---|---|---|---|---|---|
| Cast-iron | Wrought-iron | Fibres of both surfaces parallel to the motion | Surfaces unctuous | 0·143 | 8° 9′ | .... | .... |
| | | | Lubricated with tallow | .... | .... | 0·100 | 5°43′ |
| | | | Without lubrication | 0·152 | 8 39 | 0·162 | 9 13 |
| Cast-iron | Cast-iron | do. do. | Surfaces unctuous | 0·144 | 8 12 | .... | .... |
| | | | Lubricated with water | 0·314 | .... | .... | .... |
| | | | Lubricated with soap | 0·197 | .... | .... | .... |
| | | | Lubricated with tallow | 0·100 | 5 43 | 0·100 | 5 43 |
| | | | Lubricated with lard | 0·070 | .... | 0·100 | .... |
| | | | Lubricated with olive oil | 0·064 | .... | .... | .... |
| | | | Lubricated with lard and pl'bago. | 0·055 | .... | .... | .... |
| Wrought-iron | Bronze | Fibres parallel to motion | Without lubrication | 0·172 | 9 46 | .... | .... |
| | | | Surfaces unctuous | 0·160 | 9 6 | .... | .... |
| | | | Lubricated with tallow | 0·103 | .... | .... | .... |
| | | | Lubricated with lard | 0·075 | .... | .... | .... |
| | | | Lubricated with olive oil | 0·078 | .... | .... | .... |
| Bronze | Wrought-iron | do. do. | Without lubrication | 0·161 | 9 9 | .... | .... |
| | | | Surfaces unctuous | 0·166 | 9 26 | .... | .... |
| | | | Lubricated with tallow | 0·081 | .... | .... | .... |
| | | | Lubricated with lard and pl'bago. | 0·089 | .... | .... | .... |
| | | | Lubricated with olive oil | 0·072 | .... | .... | .... |
| Cast-iron | Bronze | do. do. | Without lubrication | 0·147 | 8 22 | .... | .... |
| | | | Surfaces unctuous | 0·132 | 7 22 | .... | .... |
| | | | Lubricated with tallow | 0·103 | .... | .... | .... |
| | | | Lubricated with lard | 0·075 | .... | .... | .... |
| | | | Lubricated with olive oil | 0·078 | .... | .... | .... |
| Bronze | Cast-iron | do. do. | Without lubrication | 0·217 | 12 15 | .... | .... |
| | | | Surfaces unctuous | 0·107 | 6 7 | .... | .... |
| | | | Lubricated with tallow | 0·086 | .... | 0·106 | .... |
| | | | Lubricated with olive oil | 0·077 | .... | .... | .... |
| Bronze | Bronze | do. do. | Without lubrication | 0·201 | 11 22 | .... | .... |
| | | | Surfaces unctuous | 0·134 | 7 38 | 0·164 | 9 19 |
| | | | Lubricated with olive oil | 0·058 | .... | .... | .... |
| Brass | Cast-iron | do. do. | Without lubrication | 0·189 | 10 49 | .... | .... |
| | | | Surfaces unctuous | 0·115 | 6 34 | .... | .... |
| | | | Lubricated with tallow | 0·072 | .... | 0·103 | .... |
| | | | Lubricated with lard | 0·068 | .... | .... | .... |
| | | | Lubricated with olive oil | 0·066 | .... | .... | .... |
| Steel | Cast-iron | do. do. | Without lubrication | 0·202 | 11 26 | .... | .... |
| | | | Lubricated with tallow | 0·105 | .... | 0·108 | .... |
| | | | Lubricated with lard | 0·081 | .... | .... | .... |
| | | | Lubricated with olive oil | 0·079 | .... | .... | .... |
| Steel / Steel | Wrought-iron / Bronze | Fibres of iron parallel to the motion | Lubricated with tallow | 0·093 | .... | .... | .... |
| | | | Lubricated with lard | 0·076 | .... | .... | .... |
| | | | Without lubrication | 0·152 | 8 39 | .... | .... |
| | | | Lubricated with tallow | 0·056 | .... | .... | .... |
| | | | Lubricated with olive oil | 0·053 | .... | .... | .... |
| | | | Lubricated with lard and pl'bago. | 0·067 | .... | .... | .... |
| Black leather (as used for light straps) | Oak | Fibres of the oak parallel; leather laid flat | Without lubrication | 0·265 | 14 51 | 0·74 | 36 31 |
| | | do. polished and hardened by hammering | do. do. | 0·296 | 16 30 | .... | .... |
| Ox hide (such as used for strong belts &c.) | do. | Fibres of wood parallel, rough | Without lubrication | 0·52 | 27 29 | 0·605 | 31 11 |
| | | Fibres of wood parallel, smooth | Without lubrication | 0·335 | 18 31 | 0·43 | 23 17 |
| | | | Leather saturated with water | 0·29 | .... | 0·79 | .... |
| do. | Cast-iron | do. do. | Surface unctuous | 0·229 | 12 54 | 0·267 | 14 57 |
| | | | Greased and saturated with water | 0·365 | .... | .... | .... |
| | | | Lubricated with tallow | 0·159 | .... | .... | .... |
| | | | Lubricated with olive oil | 0·133 | .... | 0·122 | .... |
| do. | Brass | do. do. | Surfaces unctuous | 0·244 | 13 43 | .... | .... |
| | | | Lubricated with tallow | 0·241 | .... | .... | .... |
| | | | Lubricated with olive oil | 0·191 | .... | .... | .... |
| Hemp | Oak | Fibres of hemp not twisted and placed in a direction perpendicular to those of the motion; fibres of the oak parallel to the motion | Greased and saturated with water | 0·332 | .... | 0·869 | .... |
| Hemp | Cast-iron | Fibres of hemp, as above | .... | .... | .... | .... | .... |
| Hemp-twist | Cast-iron | do. do. | Lubricated with tallow | 0·194 | .... | .... | .... |
| | | | Lubricated with olive oil | 0·153 | .... | .... | .... |
| Hemp-band | Oak | Fibres of the wood and direction of the cord parallel to the motion | Without lubrication | 0·52 | 27 29 | 0·64 | 32 38 |
| Hemp-plait band of small cords | do. | do. do. | do. do. | 0·32 | 17 45 | 0·50 | 26 34 |
| Old cordage 1½ in. diam. | do. | do. do. | do. do. | 0·52 | 27 29 | 0·79 | 38 19 |

the length of the tangent in the case of a pivot generated by the revolution of such a curve, the arm with which the coefficient of sliding friction acts, as given in "Des Ingenieur's Taschenbuch," is $t \times f$.

The table on pages 851 and 852 contains a very complete summary of M. Morin's experiments on the friction of plane surfaces sliding upon one another. It embraces the three conditions of clean and unctuous surfaces, and surfaces between which a stratum of the lubricant is interposed. The coefficient of friction is given for each of those conditions for both the friction of motion and the friction of quiescence, and also the limiting angle of resistance answering to the coefficients of friction in the cases of clean and unctuous surfaces. The sliding surfaces were varied from .03336 to 2.7987 square feet, and the pressures from 88 to 2,205 lbs. The surfaces of the woods were planed, and those of metal filed and polished with the utmost care; and when the friction of the clean surfaces was to be determined, any unctuosity was especially guarded against. In the experiments upon unctuous surfaces, the unguent was carefully wiped off, so that no interposing layer of it should prevent their intimate contact. In the experiments to determine the friction with unguents interposed, the extent of the surfaces bore such a relation to the pressure that a stratum of the lubricant was retained between them. The relations kept in view were such as are commonly found in the larger class of machines in which the adhesion of the lubricant to the surfaces of contact may, as respects opposition to motion caused by its viscidity, be overlooked as altogether insignificant compared with the friction. As respects the nature of the substance used in lubrication, it will be observed by comparison of the coefficient of the friction of motion, that with hog's lard and olive oil surfaces of wood on metal, wood on wood, metal on wood, and metal on metal, have all very nearly the same friction, the value of the coefficient being in all those cases included between 0.07 and 0.08. With tallow the coefficient is the same except in the case of metals upon metals; this lubricant seems therefore less suited for metallic surfaces than the others named.

*Axle and Rolling Friction.*—Axle friction has been generally supposed to follow the laws of sliding friction, with the exception that its coefficient is a smaller fraction of the total pressure applied. There are but few experimental data relating to this branch of the subject. The results of some experiments by Morin and Coulomb are given in the following table:

*Ratios of Friction to Pressure for Axles in Motion in their Bearings.*

I.—ACCORDING TO MORIN'S EXPERIMENT.

| Designation of surfaces in contact. | State of Surfaces and nature of Lubrication. | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Dry or slightly greasy. | Greasy, and wet with water. | Lubricated, and wet with water. | Oil, tallow, or hogs' lard. Supplied in the ordinary manner. | Oil, tallow, or hogs' lard. The grease continually renewed. | Purified very soft grease. | Hogs' lard with plumbago. | Greasy, very soft to the touch. |
| Bronze on bronze | .... | .... | .... | 0·079 | .... | .... | .... | .... |
| do. on cast-iron | .... | .... | .... | .... | 0·049 | .... | .... | .... |
| Iron on bronze | 0·251 | 0·189 | .... | ·075 | 0·054 | 0·090 | 0·111 | ... |
| do. on cast-iron | .... | .... | .... | ·075 | 0·054 | .... | .... | .... |
| Cast-iron on cast-iron | .... | 0·137 | 0·079 | ·075 | 0·054 | .... | .... | .... |
| do. on bronze | 0·194 | 0·161 | .... | 0·075 | 0·054 | 0·065 | .... | 0·137 |
| Iron on lignum-vitæ | 0·188 | .... | .... | 0·125 | .... | .... | .... | 0·166 |
| Cast-iron on do | 0·185 | .... | .... | 0·100 | 0·92 | .... | 0·109 | 0·140 |
| Lignum-vitæ on cast-iron | .... | .... | .... | 0·116 | .... | .... | .... | 0·153 |
| do. on lignum-vitæ. | .... | .... | .... | .... | 0·170 | .... | .... | .... |

II.—ACCORDING TO COULOMB'S EXPERIMENT.

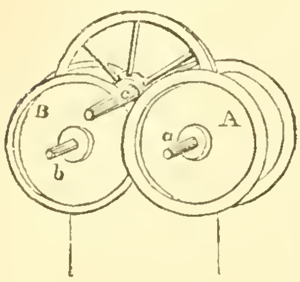
| | Dry. | Olive-oil. | Hogs' lard. | Tallow. | Greasy. | Old lubrication. | Observations. |
|---|---|---|---|---|---|---|---|
| Iron on copper | 0·155 | 0·130 | 0·120 | 0·085 | 0·127 | 0·133 | The number relative to the friction of iron on wood is deduced from a pulley, the lubrication of which, or the nature of the axle and bearings, are not mentioned by Coulomb. |
| Iron on wood | .... | .... | .... | 0·050 | .... | | |
| Green-oak on lignum-vitæ | .... | .... | .... | 0·038 | 0·060 | 0·070 | |
| do. on elm | .... | .... | .... | 0·030 | 0·050 | .... | |
| Box on lignum-vitæ | .... | .... | .... | 0·043 | 0·070 | .... | |
| Box on elm | .... | .... | .... | 0·035 | 0·050 | .... | |

Experiments were made by Coulomb with rollers, from 2 to 12 inches thick, of lignum-vitæ and elm, which were rolled along a surface of oak, by means of a thin thread passing over a roller whose extremities were stretched by unequal weights. From the results of these experiments, rolling friction appears to increase directly with the pressure and inversely with the diameter of the roller, so that the force necessary to overcome this friction may be expressed by $F = f\frac{R}{r}$, $R$ being the pressure, $r$ the radius of the roller, and $f$ the coefficient of friction derived from experiment. If $r$ be given in inches, then from these experiments, for rolling upon compressed wood, $f = .0189$; if the wood be elm, $f = .031$. These formulæ suppose that the force $F$ acts at the circumference of the roller; but if the force be applied to the axis of the rolling bodies, by which, as in every description of carriage, axle friction ensues, the required force is 2 $F$, because here the arm is only half that of the diameter with respect to the point of application.

Very few experiments have been made with a view of obtaining coefficients of rolling friction independently of axle friction, and a wide field is open to investigators in this direction. It is, however, well known that the obstruction which a cylinder meets in rolling along a smooth plane is quite distinct in its character, and far inferior in its amount, to that which is produced by the friction of the same cylinder drawn lengthwise along a plane. For example, in the case of wood *roll-*

*ing* on wood, the resistance is to the pressure, if the cylinder be small, as 16 or 18 to 1,000; and if the cylinder be large, this may be reduced to 6 to 1,000. The friction from sliding, in the same cases, would be to the pressure as 2 to 10 or 3 to 10, according to the nature of the wood. Hence, by causing one body to roll on another, the resistance is diminished from 12 to 20 times. It is therefore a principle in the composition of machines that attrition should be avoided as much as possible, and rolling motions substituted for it whenever circumstances permit.

1817.




On this principle depend the advantages resulting from the application of *friction-wheels* and *friction-rollers*. The extremity of an axle *c*, Fig. 1817, instead of resting in a cylindrical socket, is made to rest on the circumferences of two wheels, *A* and *B*, to the axles of which, *a* and *b*, the friction is transferred, and consequently diminished in the ratio of the radius of the wheel *A* to the radius of the axle *a*. This ingenious contrivance appears to have been first applied by M. Sully, in the year 1716. ("Descr. Abrégée d'une Horloge," etc., Bordeaux, 1716.) R. H. B.

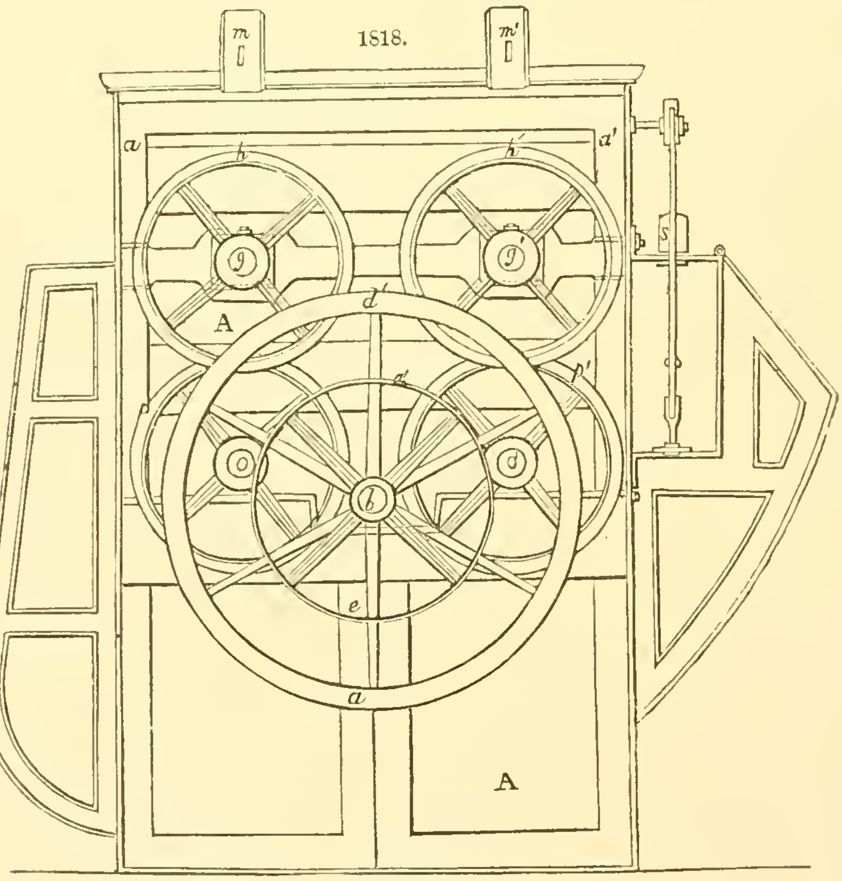
FROG. See RAILROAD.

FUEL. See BOILERS, STEAM, and FURNACES.

FULLING MACHINERY. Fulling is a process by which woolen cloths are divested of the oil imbibed for the operation of carding, and the texture is at the same time rendered much closer, firmer, and stronger. This process, also called milling, was formerly entirely performed by the fulling-stocks, Figs. 1823 and 1824. The stocks, although still in extensive use, have been greatly superseded by a superior class of machines, in which the cloth passes between squeezers, and is not subjected to heavy blows. By these machines the pressure can be regulated according to the quality and requirements of the fabric, the milling is more perfect, the power expended is less, and, not least, the disagreeable noise consequent on the use of stocks is avoided.

Figs. 1818, 1819, and 1820 represent different views of one of this class of machines. Fig. 1818 is a side elevation, Fig. 1819 a cross-section, and Fig. 1820 a front end elevation of the machine. It

1818.



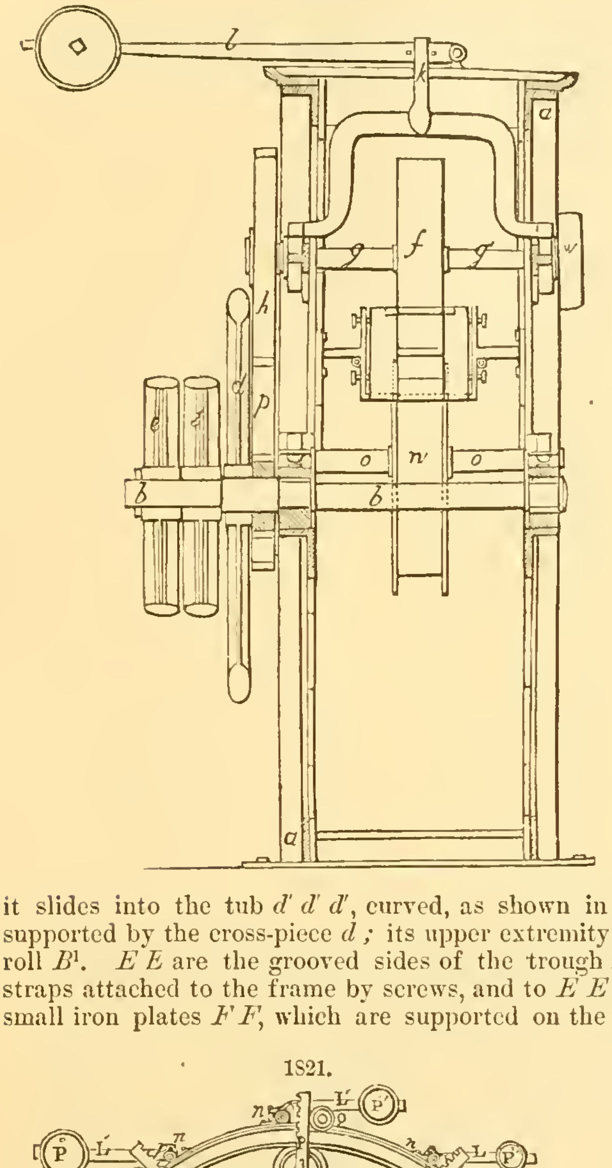

will be perceived that the machine is composed of four cylinders, *n n' f f'*, running horizontally, arranged in pairs one above the other, and two vertical cylinders, *g g'*. Both horizontal and vertical cylinders are subjected to pressure: to the former it is applied by means of the weight movable on the arm of the lever *l*, which forces down the yoke *k* on the boxes of the cylinders. The pressure is applied to the vertical cylinders by the variable weight *s*, through the levers *w*. In both cases the pressure to be exerted can be varied at pleasure.

The operation is as follows: One end of the cloth having been passed between the sets of horizontal and vertical cylinders, the two ends of the cloth are then attached together, so as to make an endless band. The machine is now set in motion by the pulley *e* on the shaft *b*, and the cloth continues to make the round between the cylinders or squeezers, falling in folds at the front of the machine, and drawn up again at the back till the washing and fulling is finished.

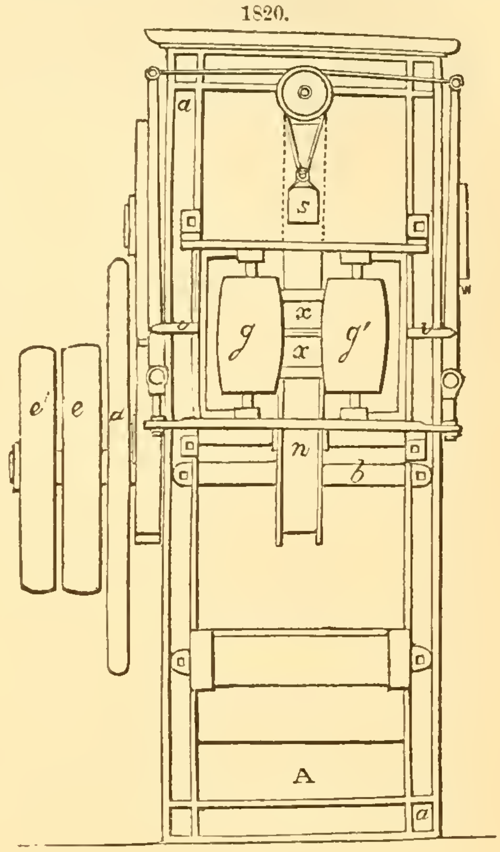
A rotary fulling-mill, still better than the preceding, is given in Figs. 1821 and 1822. Fig. 1821

is the side elevation, and Fig. 1822 the longitudinal section, showing the interior arrangement. *A A* is the main cylinder, driven by a gear; on either side are cheeks, between which the small cylinders or rolls $B^1$ $B^2$ $B^3$ revolve, and between these rolls and the cylinder the cloth passes. *C* is the lower side or bottom of a trough which receives the cloth after it has passed the roll $B^1$, and down which

1819.

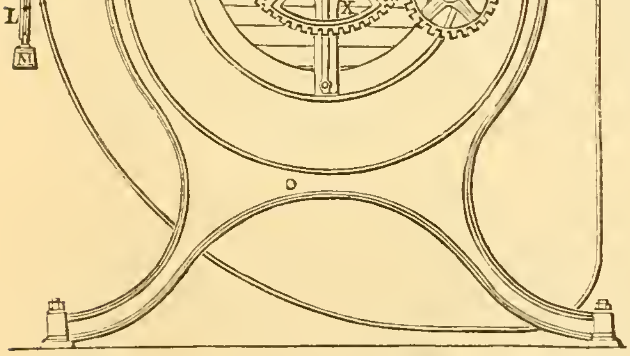


1820.

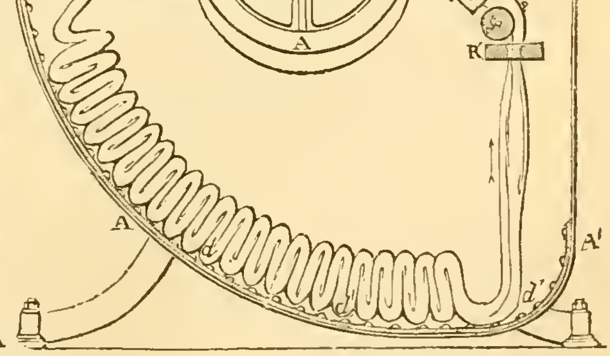


it slides into the tub *d' d' d'*, curved, as shown in Fig. 1822. *D* is the top of the trough, and is supported by the cross-piece *d*; its upper extremity touches, but without friction, the surface of the roll $B^1$. *E E* are the grooved sides of the trough; their upper extremities are held by small iron straps attached to the frame by screws, and to *E E* by pins; the centres of the sides are fastened to small iron plates *F F*, which are supported on the standards *G G*, on which they turn freely; the

1821.



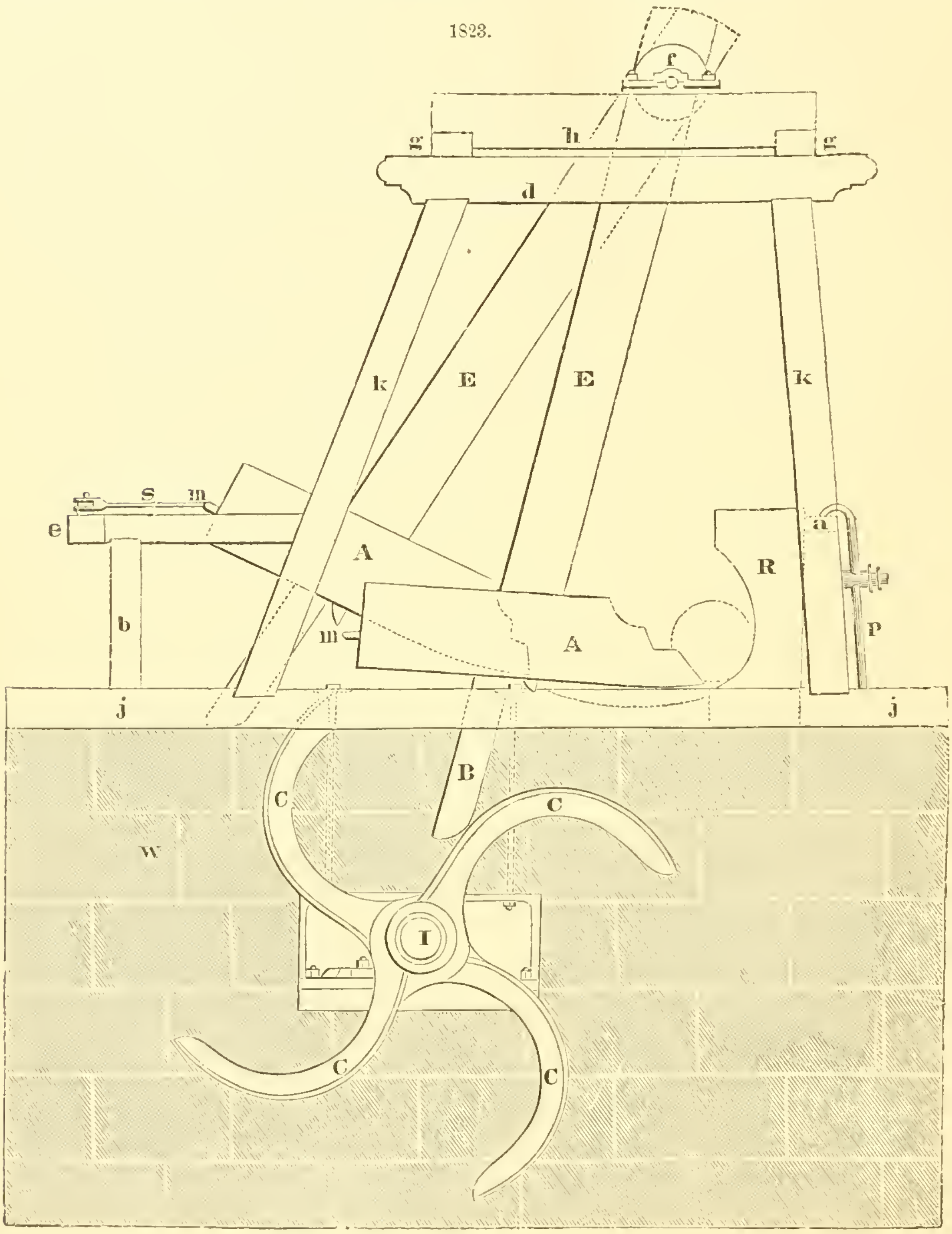
1822.



standards themselves, attached to the plates *H H*, can turn on the pivots *I I*. *L* is a cord attached to the ends of the levers *K K*, by which, through the aid of a pulley, the weight *M* tends to draw them together. *N N*, a cross-piece attached to the frame and supporting the pivots *I I*, and guide-plates $C^1$. The journals 2, 3, 4, of the rolls $B^1$ $B^2$ $B^3$, run in bearings inserted in the bars *P P P*,

whose lower extremities are maintained in a position by the guide-rings $s$, attached to the frame, which admits of a motion in the direction of their length; while at their upper extremities are racks into which play the toothed segments $p\ p\ p$, fixed in pairs on the shafts $n\ n\ n$. $P'\ P'\ P'$, weights movable on the arms of the levers $L'\ L'\ L'$, whose fulcra are at $n\ n\ n$, and attached to the toothed segments $p\ p\ p$; by these weights the force with which the rolls $B^1\ B^2\ B^3$ press on the cylinder $A$ is regulated. $Q\ Q\ Q$, guide-rolls which keep the racks in gear with the segments. $R'$, a plate perforated with an oval hole, through which the cloth is first passed, the effect of which is to straighten the folds; thence the cloth passes over a conducting roll $S$, through the short tube $R$, to the main cylinder; the tube $R$ is supported by a cross-plate attached to the frame. The draught or drawing in of

1823.

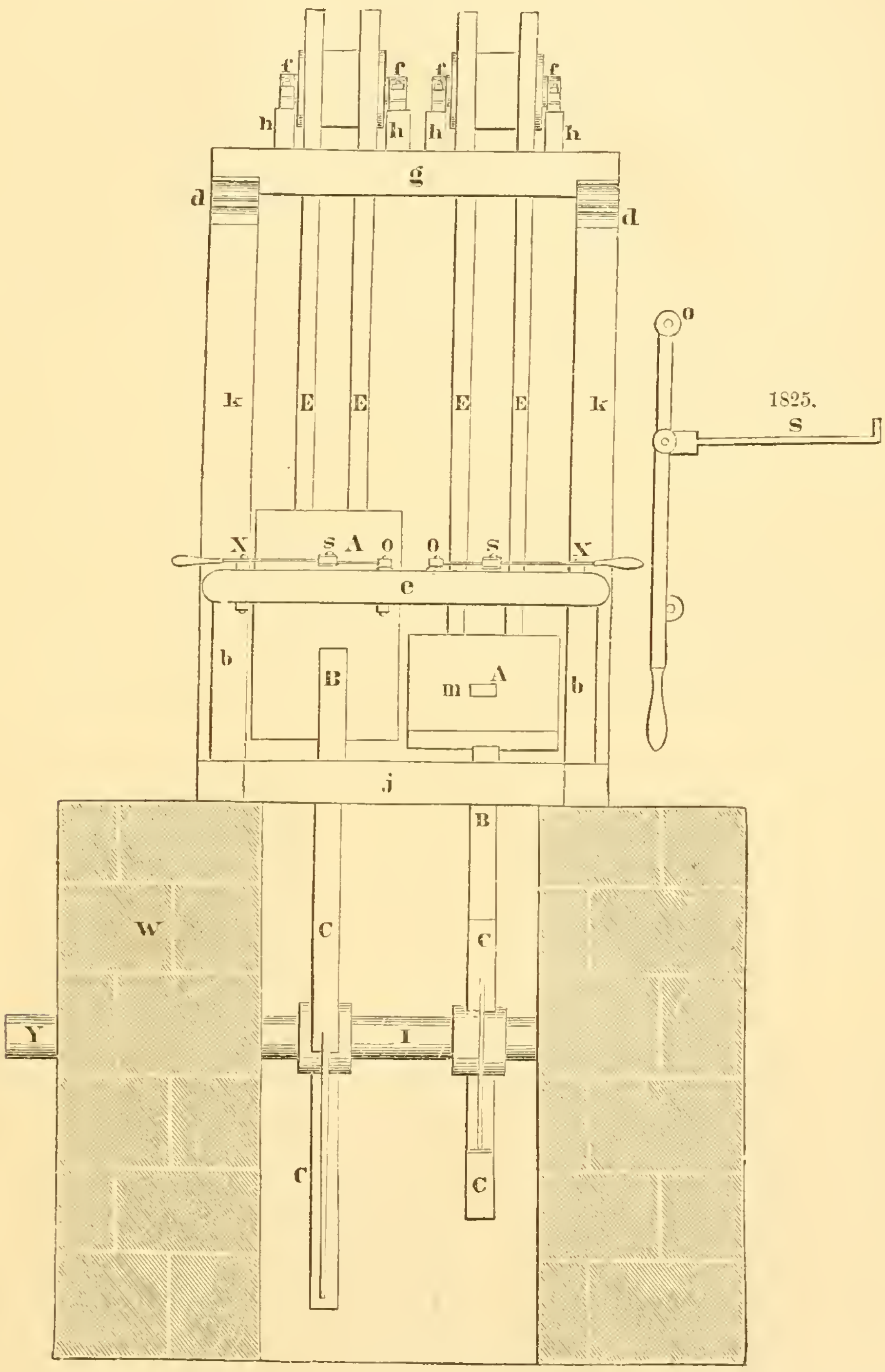



the cloth is occasioned by the pressure of the roll $B^1$ on the main cylinder, which cylinders are geared together by the pinion $N'$ and the gear $N$, on their respective shafts.

*Operation of the Machine.*—The cloth is first passed through the aperture $R'$, over the roll $S$, through the tube $R$, to the groove or space between the cheeks of the main cylinder $A$, thence beneath the rolls $B^3\ B^2\ B^1$, and is delivered through the trough $C\ D\ E$ at the back of the machine. The ends of the cloth are now fastened together, the mill is set in motion, and the operation is performed as in the preceding machine. The cloth is presented successively in a continuous round to the action of the squeezers till the fulling is finished. It will be easily perceived that the effect of the passage of the cloth beneath the rolls $B^3\ B^2\ B^1$ is a stretching of the cloth in the direction of its length, which causes a thickening or fulling of it in the width. The cloth should also undergo a compression or fulling lengthwise. This is effected by the sides $E\ E$ of the trough $C\ D\ E$; these

sides hold by iron straps at their upper extremities, at a constant distance equal to that between the cheeks of the main cylinder, while their lower extremities, by means of the pivots *G G* and *I I*, admit of a lateral motion at these extremities. The weight *M* is made to act through the levers *K K*, which brings them together and prevents the discharge of the cloth; the result is that the cloth, being still delivered by the roll $B^1$, is forced into the guide-box till the pressure is sufficient to overcome that with which the two sides of the box are brought together by the weight *M*. The sides of the box then take a nearly parallel position. The cloth escapes gently, and falls into the circular box or tub which composes the lower part of the machine. As by the weights *P′ P′ P′* the pressure on the cylinders $B^1$ $B^2$ $B^3$ can be regulated, and consequently the fulling breadthwise of the

1824.

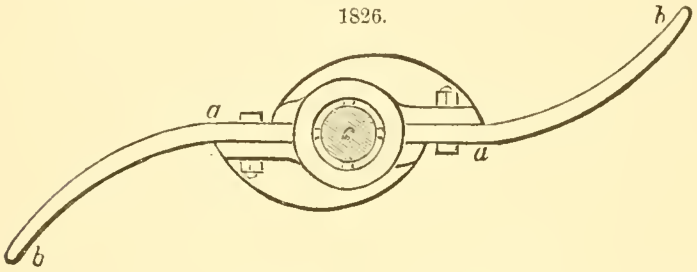



cloth, so by varying the weight *M* more or less resistance can be opposed to the discharge of the cloth, and by this means the fulling of the cloth lengthwise can be increased or diminished. A system of percussion has also been added to this machine. Small revolving or reciprocating beaters, making their blows on a fulling table, strike the cloth as it leaves the expanding trough.

Figs. 1823 and 1824 are side and end elevations of the older form of fulling-mill. *k k* is the side-framing of the machine, made of strong rectangular pieces of wood, connected together at the top by the cross-beams *d d* and the cross-rails *g g*, upon which the four pieces *h h h h* rest in positions parallel to *d d* and at right angles to the rails *g g*. The use of the beams *h h h h* is, besides affording additional stiffness to the framing, to carry the four pedestals *f f f f*, in which are the working centres of the *feet* or beaters *A A*. These are suspended by the *legs* or pieces *E E*. From the under side of the feet, the *lifters* or wipers *B B* project; and by means of these the feet are con-

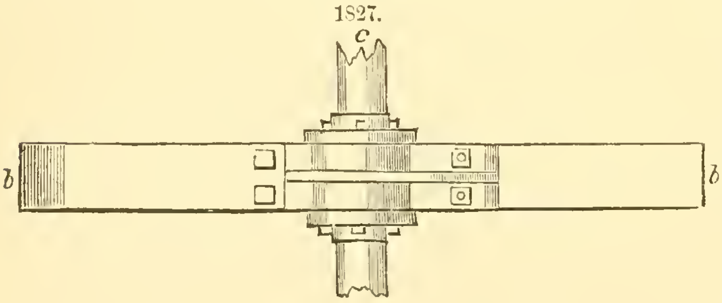
tinually thrown back by the two pairs of wipers *C C C C* upon the common driving-shaft *I*. The upright framing is secured at bottom by cross-beams, into which the uprights *k k* are mortised; and these are bolted down usually to a solid foundation of stone. *R* is the *rowhead* of the receptacle or trough into which the cloth to be washed is put, and in which the beaters *A A* are suspended. The end *R* of this receptacle is formed of two or more blocks of wood, commonly oak, firmly jointed together, and is shaped internally into a parabolic curve, against which the cloth is pressed by the beaters *A A*, alternately, during the operation of washing. By this means the cloth is continually, but slowly, being turned round by the action of the beaters upon it. Water is meantime supplied from the cistern *a*, which extends across the back of the framing, through a series of small holes pierced in the back of the trough *R*, and is let off through holes pierced in the bottom of the same. The centre *a* is filled from a well or other reservoir, by the pipe *P*. The feet *A A*, as above described, are worked by the double wipers *C C C C* on the wiper-shaft *I*. These wipers, being set pair and pair at right angles to each other, work the feet alternately; so that when one foot is being caught by its wiper, the other is at that moment being released. The feet thus rise and fall alternately, and make each two strokes during one revolution of the shaft *I*. Into the *heel* of each foot is screwed a staple of iron *m*, which receives a hook-catch *s*, jointed upon a lever, having its centre of motion at the stud *o*. The use of this arrangement is to keep up the feet when the cloth is being taken out of the trough. This lever and catch are represented separately by Fig. 1825. The wiper-shaft is usually connected to one of the main shafts of the works by a friction-coupling of some kind, for the purpose of starting the machine with as little shock as possible. Various efficient and simple couplings for this purpose are described under COUPLINGS AND CLUTCHES.

1826.




In the machine from which these drawings were made, the wipers are of cast-iron. This, however, is not to be recommended, as the wipers are liable to break by concussion with the lifters *B B;* and, being cast pair and pair, in one piece, they are difficult and costly to replace. The most approved, and now the most common mode, is to cast strong centres which fit upon the shaft *I*, and to attach to these malleable-iron wipers, which are not only less liable to fracture, but are also replaced with more facility in cases of failure from accident or decay. This arrangement is represented by the annexed woodcuts, of which Fig. 1826 is an elevation, and Fig. 1827 a plan of a pair of the wipers. *C* is the wiper-shaft, upon which the cast-iron centre is keyed. This centre is cast with two flange-pieces projecting in the plane of the axis, and strengthened by feathers on one side. These pieces are of the same breadth as the malleable-iron arms *a b*, *a b*, which are to be bolted to them at *a a*.

1827.




In Dusseaux's improved fulling machine exhibited at the Paris Exposition of 1878, free fall-hammers inclined at an angle of about 60° are employed. These are lifted by cams placed at right angles on the driving-shaft. The hammer-heads are of wood and stepped underneath. The machine is run by an ordinary belt-pulley. The time of ascent of the hammers is to the descent as 5 to 1. Desplas's fulling machine, which was also exhibited in the same Exposition, has rubber cylinders between which the fabric is pressed. For other machines for treating cloth, see CLOTH-FINISHING MACHINERY.

FURNACES. Furnaces, as used in the arts, may be defined as the arrangements under which fuel is burned to produce heat, for the purpose either of inducing permanent changes in the substances heated, or of preparing them, by softening or fusion, for subsequent treatment. This excludes two of the applications of fuel which together take up the larger proportion of that consumed: the domestic use, namely, for cooking and for warming, lighting, and ventilating inhabited places (see GAS, ILLUMINATING, APPARATUS FOR MANUFACTURE OF, and STOVES AND HEATING FURNACES); and that for the generation of motive power (see BOILERS, STEAM).

Furnaces may be divided into those in which solid fuel is intermixed with or directly surrounds the matters to be heated, and those in which the heating is done, in one way or another, by flame, without direct contact between the fuel and the object acted upon. The characters of the fuel best fitted for these two kinds of furnace are essentially different. Where the matters to be acted on, or the vessels that contain them, are in direct contact with the fuel, as in a smithy fire, a cupola, or an ordinary coke furnace for melting steel or brass in crucibles, an intense local heat is required in the mass of the fuel itself, and any heat developed above its surface is useless. In flame furnaces, on the other hand, such as those for glass-melting or for puddling or heating iron, in which the materials to be heated are not imbedded in the fuel, but placed in a chamber above or at the side of it, the heat made use of is that of the flame; the heat that is carried into the working chamber by the current of gases rising from the fire, together with that due to the further combustion of these gases on admixture with an additional amount of air. Thus, for furnaces of the first class, the most suitable fuel is one, such as charcoal, coke, or anthracite, consisting of nearly pure carbon,

free from volatile matter, as this is useless in them as a source of heat, and the driving of it off renders latent a certain amount of that generated by the combustion of the carbon, and so lowers the temperature of the fire.

In flame furnaces, a lowering of the temperature at the fire-grate, where the air and the solid fuel meet, is immaterial, or may be even advantageous, as tending to diminish loss by radiation and to preserve the furnace from injury by excessive heat. The only use of the heat at the grate is to generate a full supply of combustible or partly burned gases at a high temperature, which in completing their combustion, as they pass over the working bed, shall heat as strongly as possible the matters placed there. The fuel preferred for use in such furnaces is thus either a combustible gas, or a solid fuel containing hydrogen as well as carbon, such as coal or dried wood, that will produce on burning a long and powerful flame. A flame, it is true, may be obtained from fuels that contain little else than carbon and mineral matter, by burning them in a thick bed, so that the greater part or nearly the whole of the $CO_2$ formed in the first instance by the combustion of the carbon is transformed into CO as it passes up through the mass, and by introducing with the air as large a proportion of steam as can be used without lowering the temperature of the fire. The steam is decomposed by the hot carbon, producing, according to the temperature and thickness of the fire, a mixture of either H and $CO_2$ or H and CO. The gases thus generated, together with the mixture of CO and N produced by the passage of the air itself through the mass of fuel, flow forward into the working chamber, and there burn, on mixing with a further supply of air introduced above the fire.

I. Furnaces in which Fuel and Matter to be Heated are Mixed.—*Calcination Furnaces.*—Examples of the simplest form of the class of furnace in which solid fuel is mixed directly with the matters to be heated are the heaps in which brick-clay is burned to make ballast, and in which iron and other ores are often calcined. In these, the ore or dried clay, in pieces of convenient size, is thrown into a heap together with a little coal; and the mass, being lighted at one end, burns through to the other. In calcining such heaps there is a considerable waste of heat, as a great proportion of the burned gases from the fire pass off at a high temperature; and when the calcination is completed, all the heat that the red-hot mass contains is lost. In an ordinary lime-kiln, a much larger proportion of the heat produced is utilized, and the amount of this required is proportionately reduced. (See Kiln.)

*Crucible Furnaces.*—The small furnaces fired with coke that are commonly used for melting steel or brass in crucibles require no detailed notice. In these the crucible is imbedded in the fuel, and a rapid combustion and high temperature are maintained round it, by closing the upper part of the furnace and connecting it to a high chimney. (See Casting, Crucible, and Steel.)

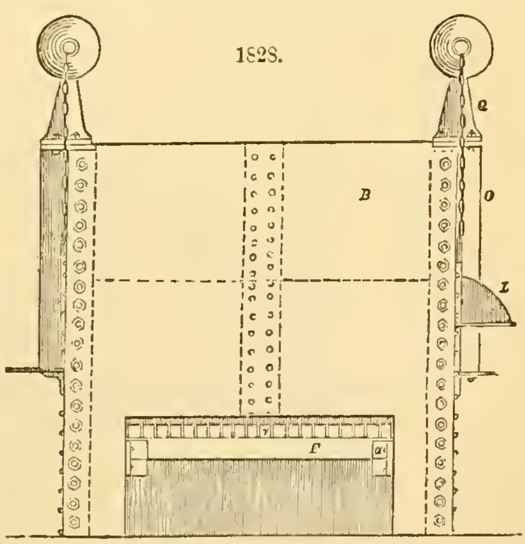
*Forge Furnaces.*—Where, as in the case of a smithy fire, the top of the furnace cannot be conveniently closed in, or where a keener combustion is required than can be obtained by chimney draught, the plan is adopted of forcing air into the fire by mechanical means. (See Blowers, and Forge.)

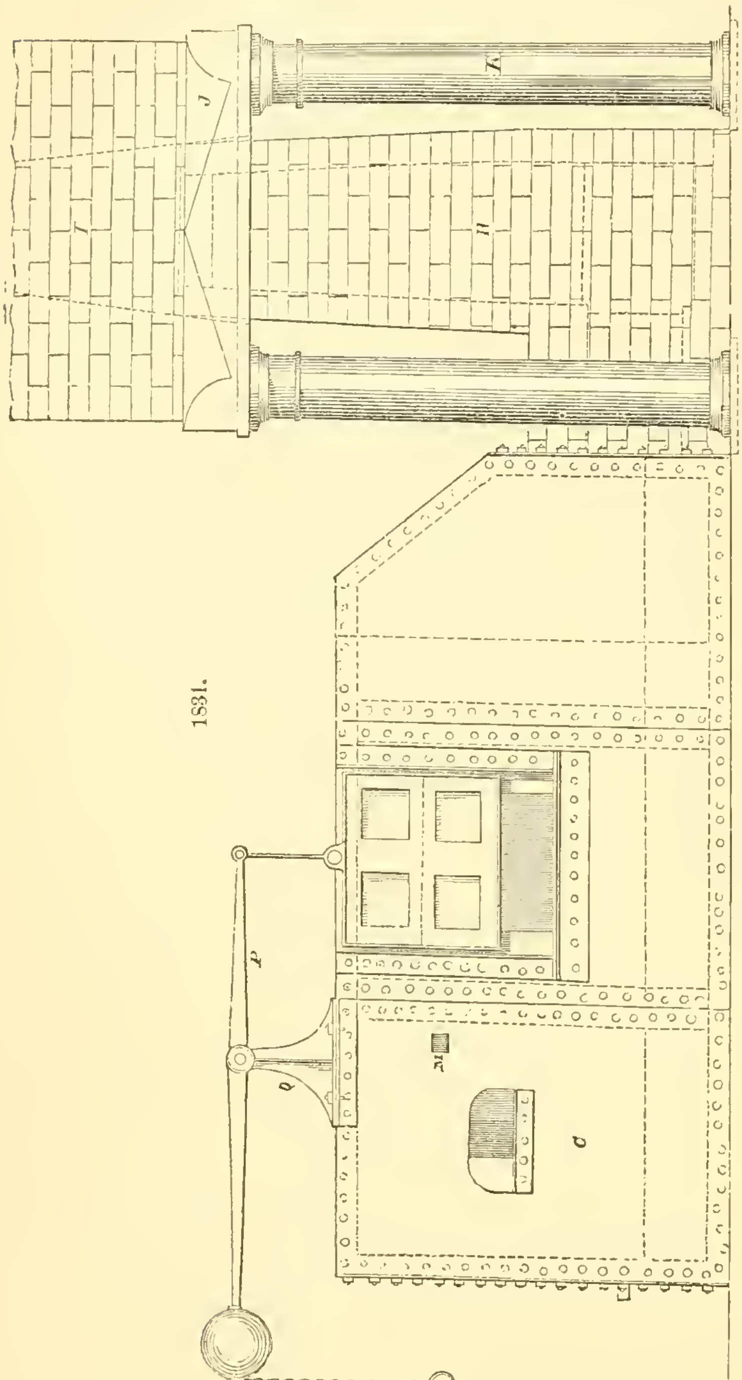
*Blast Furnaces and Cupolas* are largely used in smelting the ores of iron, lead, and copper, and in fusing cast-iron and other substances. In all these, the fuel and the materials to be melted or otherwise acted on are charged together into the upper end of a vertical shaft, and the combustion is maintained by air forced in through one or more openings or tuyeres near the bottom. (See Blowers, Furnaces, Blast, and Furnaces, Cupola.)

II. Flame Furnaces.—These are very varied in form and character. Their useful effect is obtained by bringing a flame or current of highly heated and burning gas into contact with the matters to be acted on, instead of imbedding these in or mixing them with the solid fuel.

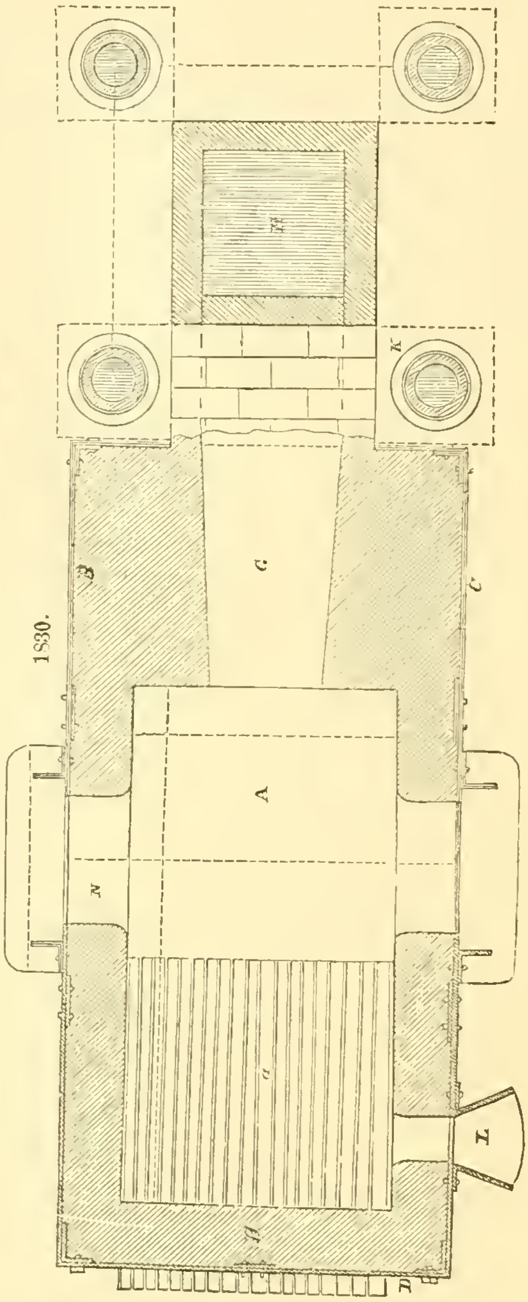
*Reverberatory Furnace.*—The ordinary reverberatory furnace, with a fire-grate, a flame-chamber or working chamber, and beyond that a flue leading into the chimney, is well known. An example is given in Figs. 1828 to 1831. *A A* is the hearth and building upon which the furnace is erected. It is lined throughout with fire-bricks, and the hearth is formed at a slight inclination, so that the flame and heat may more effectually react from the arched roof upon the work placed on it. *B B*, the roof and sides of the furnace, also formed of fire-bricks. The roof is arched throughout its entire length, in order that the heat may be reflected and concentrated upon the work placed on the hearth. *C C*, the sheet-iron sides of the furnace, by which the brickwork is secured and retained in its proper form. *D D*, the end plates for binding the side plates together. Instead of being riveted to the side plates, they are secured by bolts and nuts, so that the whole structure may be easily taken asunder when it is necessary to rebuild the furnace. *E*, the ash-pit. *F F*, cross-bearers of wrought-iron for supporting the furnace-bars *a a a*. The ends of the bearers rest in small cast-iron brackets *b b*, secured to the sides of the ash-pit. *G*, the passage to the chimney, formed in continuation of the arch of the roof. *H H*, the chimney, constructed internally and throughout its entire height of fire-bricks. *I I*, corner-pieces of ordinary bricks built upon the angles of the interior chimney to give stability to the whole structure, which is further bound together by bolts *d d d* passing through the small cast-iron pieces *c c c*. *J J*, cast-iron sole-plate for supporting the brickwork of the chimney, and which is itself supported by *K K*, four strong cast-iron columns resting on a solid foundation

1828.

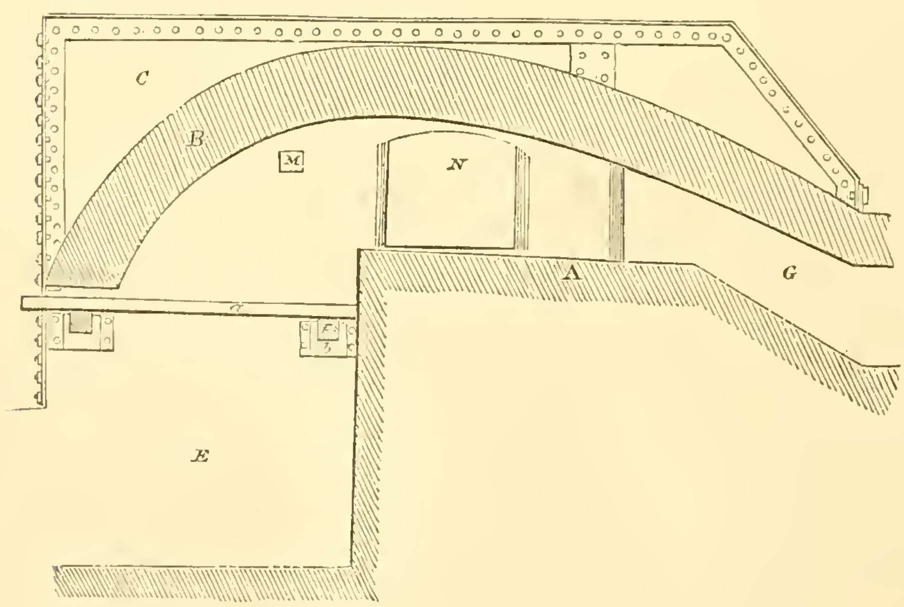




1831.



1830.



1829.

of mason-work. *L*, the stoke-hole, through which the fuel is introduced into the furnace. The mouth of this stoke-hole is so constructed as to admit of its being stopped with a piece of coal when the furnace is in full operation. *M*, a small square aperture in the side of the furnace by which the attendant is enabled to inspect the state of the furnace without interrupting the progress of the work. It may be stopped with a single brick. *N N*, the main openings into the furnace, through which the shaft or other work to be heated is passed. *O*, the sliding door by which the aperture *N* is guarded. It consists of a square cast-iron frame, lined internally with fire-bricks, and fitted to slide vertically between guides of angle-iron. *P P*, levers working upon the cast-iron brackets *Q Q*, surmounting the furnace. They are loaded at the outer ends with counterweights, and attached by short connecting-rods to the doors *O O*, so as to enable the stoker to raise or lower the latter with the utmost facility. *R*, a register or damper surmounting the chimney, for the purpose of regulating the draught of the furnace. It is brought within the command of the attendant workman by means of a long chain or wire *e e*, depending from the lever upon which it is hung.

*Gas Furnaces.*—The most important modification of this form of furnace is the regenerative gas furnace of Messrs. Siemens, for which see FURNACES (GLASS-MELTING), IRON-MAKING PROCESSES, and STEEL. The Ponsard furnace differs from the Siemens in that the air only is heated by the regenerator. The gas-producer is placed close to the furnace, and the gas from it taken directly, without further heating, to the point where it is burned. A theoretically advantageous modification of this furnace is to supply the gas-producer as well as the working chamber of the furnace with highly heated air from the regenerator.

The following practical directions are from *The Engineer*, Nov. 30, 1877:

"The success of a direct-acting gas furnace, or, indeed, of any gas furnace, will greatly depend on the suitable form and arrangement of the producer—more especially with reference to the peculiar kind of coal to be burnt. The gas should as much as possible be made to rise up toward the combustion-chamber, more especially in cases where only the natural draught of the chimney is employed. The simplest means of doing this is to place the producer under the level of the ground. The brickwork must be very good; the mortar of a fat clay, with a sharp quartzose sand; good firebrick and fire-clay for the parts exposed to great heat. Herr Ramdohr strongly recommends mixing cheap treacle in the mortar to be used. The number and dimensions of the stoking-holes must be made to suit the caking or non-caking properties of the fuel. It is advantageous to make several at first, which can afterward, in the course of working, be bricked up if found unnecessary. An eyepiece, best made of a plate of mica set in an iron frame, is very useful. A step-grate is generally best for slack, but an ordinary flat grate, set either horizontally or on an incline, suits caking coal better. The grate should be made of as small an area as practicable, and its bars cast of good soft foundry iron, it being of great importance that they should not bend under the heat. In order to prevent the loss of tar, the need of a tar-trap, the chances of losses of gas, of explosions, and the deposit of soot, the gas-channels between the producer and gas-chamber should be as short as is consistent with the fire not being in communication with the producer itself. If long gas-channels be absolutely required, they must be laid 18 inches to 3 feet under the ground; but they always act as condensers for the tarry products in the gases. The horizontal section of a gas-producer will be generally square; stoking- and cleaning-doors must be provided for easily removing the ashes. A circular section is, however, much to be preferred, whenever it can be adopted, as sharp corners catching the slack are thereby avoided. A damper is necessary, in order to regulate and shut off the gas. In any case great care should be exercised in setting the gas-channels on a gradual incline between the producer and the spot where they are to be burnt.

"The layer of fuel in immediate contact with the grate is set alight, and is the prime agent of the process; the layers above gradually going through the three successive stages of drying, coking, and burning. If the fuel in the producer were pure carbon, burning to carbonic oxide with the exact modicum of 6 lbs. of air, each pound of carbon would give off 4,400 thermal units, which, divided by the mean specific-heat times the weight of 7 lbs., would give more than 2600° F. as the elevation of the temperature; but it is more probable that at least 1000° must be struck off this for sundry losses, bringing the heat down to 1500° at the very most, in round numbers. The comparatively low temperature at which the producer can be worked very considerably diminishes the wear and tear of the bars; and, as compared with the loss of this kind in ordinary furnaces, the saving is generally one-half in this item. The lower temperature of the clinkers prevents their acting as a flux with the iron and eating it away.

"The capital point to be borne in mind is that, if the air be in excess, then carbonic acid is evolved; the carbon must be in excess to obtain the required carbonic oxide.

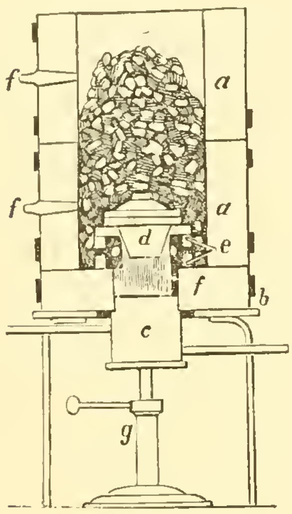
"It is evident on consideration that a very important and considerable source of economy in the use of a gas-producer is that no loss can occur through unconsumed bits of coal dropping down between the fire-bars into the ash-pit. In some producers a steam-jet is employed to induce a current of air, but the decomposition in this way of steam into its elements is a very uncertain operation.

"The combustion-chamber has the function of mixing the gases with the atmospheric air, in order to oxidize (to burn) them. The apparatus for mixing the air and gases either consists of a suitable number of concentric double jets—one for the gas, the other for the air—or the air is blown through a number of small tuyeres, or narrow slits, set at a certain angle against the current of gas as it streams out of an oblique annular slit; or, lastly, one of the two is caused to impinge against a fire-brick screen, thereby breaking it up into numerous currents, and bringing them into contact with the stream of the second fluid as it issues from a concentric outlet. Generally, the best means of combination is to bring the pair of streams at an angle against each other, and as little as possible in a parallel direction. In order to obtain an intense heat, it is best to let the gas flow out horizontally, directing the air at a sharp angle on to the stream of gas. The specifically lighter gas strives to rise

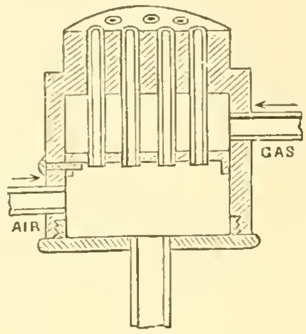
up through the stream of air, thereby mixing itself so rapidly with it that instantaneous combustion takes place. By regulating the respective quantities of gas and air, it is very easy to obtain either a reducing or an oxidizing flame, as required. Generally speaking, the combustion-chamber should be easily looked into from the outside. The outlets are best made of equal cross-sectional areas, and the respective quantities proportioned to each other by means of dampers or valves. It is necessary to be careful not to let in an excess of atmospheric air, as otherwise the great saving in fuel of at least one-third or a quarter, compared with the common grate, is lessened."

Griffin's blast gas furnace, for metallurgic operations requiring high heat, is shown in section in Fig. 1832. Two fire-clay cylinders, *a a*, form the body of the furnace. They rest upon a perforated

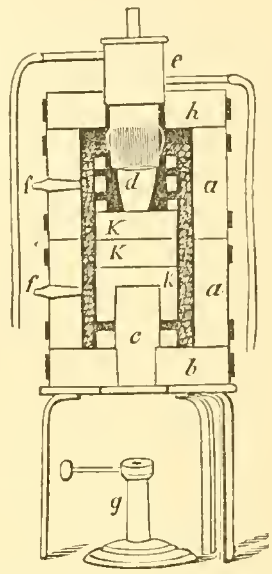
1832.




1833.

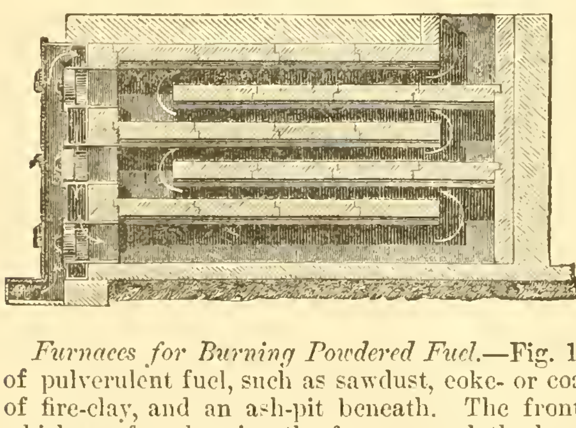



1834.




fire-clay plate *b*, into which the gas-burner, *c*, is introduced. A plumbago crucible, *d*, sets upon a perforated plumbago cylinder, *e*, and is covered to a considerable depth with quartz pebbles from half an inch to an inch in diameter; *f f* are plugs which may be removed to admit of inspection. The burner is represented in Fig. 1833, and consists of two chambers of cylindrical cast-iron, one for the reception of air and the other for gas. Tubes, varying in number from 6 to 20 or more, pass from the air-chamber through the gas-chamber, and through the axes of tubes passing from the latter, thus securing admixture of the combustible gases. A stand *g*, Fig. 1832, supplied with a thumb-screw, holds the burner at any desired distance below the crucible. The gas is supplied at the usual pressure, but the air is urged with a bellows or other blowing machine at about 10 times that pressure. In the experiments made by the inventor, the gas and air pipes were of half an inch calibre and 10 inches long, the gas having a half-inch and the air a five-inch water-pressure. The quantity of gas used per hour was about 100 cubic feet. Fig. 1832 represents the furnace with the gas-burner in an erect position, but it is perhaps more frequently used at the top, inverted, as shown in Fig. 1834, in which an additional perforated clay plate, *h*, is laid on the top of the upper clay cylinder. Into the perforation the burner is introduced, and when in action throws its flame down upon the top of the crucible, *d*, which is now placed upon a foundation of clay plates, *k k k*, raised to the proper height, and of such a size as to leave a vacant space between them and the clay cylinders, which is filled with quartz pebbles, and through which the burned gases pass on their exit, which is now through perforations in the two lower clay plates. The hot gases give up nearly all their heat to the pebbles, and escape at a much lower temperature than would be supposed. The following experiment shows the power of this furnace: A clay crucible, 3 inches in both diameters, was filled with 24 ounces of cast-iron, and not covered. The flame being thrown directly upon the iron, it was soon covered with a crust of magnetic oxide. In 20 minutes the crucible was removed, and a hole being broken through the crust, 20 ounces of melted iron was poured out. In the same furnace 16 ounces of copper can be fused in 10 minutes, commencing with the furnace cold, or in 7 minutes after it is hot. Gore's gas furnace is heated by a burner in which the air and gas are more thoroughly mixed previous to ignition than in Griffin's, but it is generally used in smaller operations.

1835.



*Furnaces for Burning Powdered Fuel.*—Fig. 1835 represents Perret's furnace for burning any sort of pulverulent fuel, such as sawdust, coke- or coal-dust, etc. It consists of four stories or chambers of fire-clay, and an ash-pit beneath. The front is pierced with three openings, the upper pair of which are for charging the furnace, and the lower one affords access to the ash-pit. The furnace is fed with air previously heated by circulation in a chamber in front of the doors, and afterward led in through the ash-pit. Combustion is thus effected at the elevated temperature due to the heating of the air and the close approximation of the platforms, and the incineration may be carried to

extreme limit. About 10 kilogrammes of fuel are burned per hour and per square metre of platform surface.

*Crampton's furnace for burning powdered fuel* is a remarkable deviation from the ordinary form of flame furnace. The coal is finely ground, and by a mechanical feeding arrangement is led into a jet of air from a fan, at a pressure equal to 3 or 4 inches water-column, by which it is carried forward into the furnace. In this the jet of mixed coal-dust and air takes fire and burns like a jet of combustible gas, except that the flame is solid, and not hollow like a gas-flame burning in air. (See IRON-MAKING PROCESSES.)

Among the directions in which improvements have been effected in flame furnaces of the ordinary type are the use of the waste heat to raise steam, a system now carried out to a greater or less extent in all iron works where such furnaces are used. The Newport furnace of Mr. Jeremiah Head (see *Journal of the Iron and Steel Institute*, 1872, p. 220) may be taken as an example of such furnaces. In this the blast-pressure is obtained by a steam-jet, and the resulting damp air is heated to about 290° C. by passing it through a cast-iron heating stove, round which the waste flame is led on its way to the chimney. The hot blast is conducted partly under the fire-grate, and partly to a row of holes in the furnace roof immediately over the fire, through which a supply of air is thus introduced, sufficient to complete the combustion of the gases rising from the fire.

Another improvement is the employment of a blast or forced draught under the fire-grate (the air in it being frequently more or less heated), in order to allow of burning cheaper small coal, and to give a command, such as that possessed by the regenerative gas furnace, over the pressure in the working chamber. Price's retort furnace (for which see IRON-MAKING PROCESSES and *Journal of the Iron and Steel Institute*, 1875, with maps, etc.) is an example of this class.

Arrangements have also been devised for preventing the cooling down of the fire each time that fresh fuel is put on, and the rush of cold air into the furnace through the opened fire-door when a pressure is not maintained in it by blast. Frisbie's feeder, designed for this purpose, consists of a movable charging-box, which when filled with coal is pushed up into the middle of the fire-grate, so that the surface of the fire remains always hot; and as the distillation of the gases from the raw coal goes on continuously, the fire remains uniform in character, and may be readily kept smokeless. (See *Iron*, viii., 516.)

*Natural Gas in Furnaces.*—When hydrogen and hydrocarbon gases are found to flow naturally from bore-holes penetrating to beds of coal or shale, they form a valuable fuel, which is made use of to a considerable extent. In some parts of Pennsylvania, from bore-holes put down for petroleum, a supply of gas, consisting chiefly of marsh-gas ($CH_4$) mixed with other hydrocarbons and with hydrogen, is permanent and apparently inexhaustible. Messrs. Rogers & Burchfield of Leechburg, Armstrong Co., Pa., were the first to use this gas in their puddling furnaces. The only change necessary in the latter was to brick up the bridge of the furnaces and let the gas in through iron pipes, supplying air by a blast. Blast-pipes were also inserted in the crown of the furnace in such a way that the blast should strike the metal at an angle of 90°, blast being let on at the commencement of the boil. A notable economy in iron production has resulted from this utilization. The most remarkable gas wells in the United States are those located in Parker township, Butler Co., Pa. For heating, the gas is a perfect fuel, causing little waste and protecting the furnace bottoms, while the transparency of the flame allows the heater to see each pile at any time. The quantity issuing from a half-inch pipe suffices to heat up and supply a puddling or heating furnace. (See *Engineering and Mining Journal*, March 18, May 22, and June 26, 1875; also "Iron Manufacture in America," Pearse, Philadelphia, 1876.)

*Petroleum Furnace.*—A petroleum furnace, to work successfully, should be so constructed as to secure intimate mixture of the gases, complete combustion in the body of the furnace, and a supply and pressure of the incandescent steam, air, and oil adjustable to the varying working conditions. The Eames furnace, which has given successful results on trial, is constructed as follows: The shape of the body of the furnace differs but little from the ordinary iron furnace, but in place of the fire-place and ash-pit are a vapor-generator, a superheater, a mixing chamber, and a combustion-chamber, while in close proximity, as a very important part of the apparatus, is a small force-pump. The superheater is a double casting, inclosing the fire, so chambered that the steam which enters it is brought in contact with ample heating surface before passing into the vapor-generator, about 150 lbs. of coal per diem being used in this. The vapor-generator is a cast-iron vessel of about 18 × 30 inches internal dimensions, placed over the superheater, and containing a number of shelves or plates set one above another, projecting alternately from opposite sides. Next in order is the mixing chamber, where the steam and oil vapors are mingled with the proper amount of air; and beyond this, occupying the place of the usual bridge-wall, is the combustion-chamber, which is an indispensable part of the apparatus, though it consists simply of a cellular tier of fire-bricks placed on end and having a horizontal thickness of 18 inches. Within these cells the combustion begins. From a tank placed in any convenient position the pump draws the petroleum, and forces it, at about 10 lbs. pressure, into the vapor-generator in a very slender stream, where it flows downward in a thin layer, dropping from shelf to shelf. It thus meets the opposing current of superheated steam which passes upward from the superheater; thence the combined vapors or gases pass through a pipe to the mixing chamber to receive the required amount of air, and from this into the cellular combustion-chamber, where begins the combustion, which is completed in the furnace itself. For the purpose of guaranteeing absolute safety in the use of this fuel, the pump is fitted with what is called an equalizing valve, which absolutely regulates the flow of the oil into the generator, and at the same time interposes an insurmountable obstacle between the generator and oil-tank to any chance reaction of gases or flame. Pressure-gauges on the oil-feed pipe and on the generator serve to give further security in the manipulation of the apparatus. Of late years, in repeated instances of continuous working, the actual efficiency of petroleum in firing boilers has been shown to be from two to three

times greater than that of the best solid coal, weight for weight, and in puddling and heating furnaces from four to six times greater; while in steel-melting furnaces its superiority is still more manifest, its thermal effects being more decided the higher the temperature required.

See papers on "Liquid and Condensed Fuel," by Captain Selwyn, R. N., in *Engineering*, ix., 310, and v., 321; "A Treatise on Metallurgy," Crookes and Rohrig, vol. iii., London, 1870; and "Metallurgy (Fuel)," Percy, London, 1875.

*Heat utilized in Furnaces.*—In nearly all furnaces, the amount of heat that is utilized is an extremely small proportion of the total heat due to the combustion of the fuel; the greater part being carried off by the burned gases, or lost by conduction and radiation. M. Gruner calculates that in the fusion of steel in crucibles in ordinary coke furnaces, the heat utilized does not exceed 1.7 per cent. of the total amount that the fuel would be capable of giving out if perfectly burned; and that even the extreme supposition that half the fuel is burned to CO, the heat utilized amounts to only 2.6 per cent. of that evolved. In flame furnaces the proportion of heat utilized is higher, reaching as a maximum 15 to 20 per cent. of the total heat due to the amount of coal burned, in well-arranged regenerative gas furnaces for heating iron. In those arrangements in which there is little heat lost by external cooling, and in which the heat of the products of combustion is most fully utilized, the useful effect is much higher; thus in large blast furnaces M. Gruner estimates that it is as much as 70 to 80 per cent. of the heat actually developed in the furnace and introduced into it by the blast, or between 40 and 50 per cent. of the total heat that the fuel could evolve if completely burned; and in the annular Hoffman brick-kiln (see BRICK-MAKING MACHINERY), it is estimated to amount also to between 70 and 80 per cent. of that given out by the fuel. The greater the proportion of heat evolved that is lost in the burned gas, the less the difference is between the temperature of the flame and that required to be maintained in the working chamber; for as soon as any portion of the flame is cooled down to the temperature of the matters to be heated, however high this may be, it can impart no more heat to them, and must be drawn away and replaced by hotter flame from the fire. Hence a small increase in the initial temperature of the flame, such as that obtained by effecting the combustion of the fuel by means of a moderately heated blast, or a small diminution in the proportion of heat lost from the working chamber by external cooling, effects a great saving in the consumption of fuel that is required to do a given amount of work.

The effect of a high flame-temperature on the proportion of heat utilized is strikingly shown by the very economical working of furnaces on Deville's system, that of burning coal-gas with oxygen instead of with air. The theoretical temperature of such a flame, if not limited by dissociation, would probably amount to 7000° or 8000° C., and it is in any case far above the fusing-point of platinum, which is estimated at about 1900° C. In an example, of which M. Gruner gives particulars (see *Annales des Mines*, 1876), of the fusion of a charge of 250 kilogrammes of platinum by this method, the cold furnace was heated up, and the metal melted in it, in 1¼ hour, with a consumption of only 848 cubic feet of gas; the proportion of heat actually utilized in the fusion of the metal being 14 per cent. of that due to the combustion of the gas. Thus, on account of the intense heat of the oxyhydrogen flame, as good an economical result was obtained in this little furnace as in the best of flame furnaces used in ordinary metallurgical work; though the proportionate loss of heat from the surface-cooling of so small a furnace (a little trough not more than 30 inches long) must have been enormous. (See "Furnaces for producing High Temperatures," *Engineering*, xi., 181.)

The diminished proportion of heat that is lost by surface-cooling in the case of large furnaces, and the consequent higher temperature of their flame, render them in all cases much more economical in fuel than furnaces of smaller size. In the case of ordinary puddling furnaces, for instance, where the coal consumption in those working 500-lb. charges is about 2,350 lbs. per ton of bar produced, the consumption is reduced to 1,800 lbs. per ton in working 1,000-lb. charges, and to 1,500 lbs. per ton in still larger furnaces working 1,500-lb. charges. In the welding furnaces in use at the Woolwich Arsenal, the larger the furnace is, the higher by actual experiment is the temperature of the flame as it passes over the bridge, and the smaller is the amount of coal required per ton of metal heated. A furnace of ordinary size, heating 6 tons at a charge, consumes about 800 lbs. of coal per ton; a larger furnace, heating a charge of 13 tons, does the work with 700 lbs. per ton. The largest furnace of all, capable of heating at once a mass of iron weighing 65 tons, gets this up to a full welding heat with a coal consumption of only 550 lbs. per ton. In copper-smelting, glass-making, and other work, large furnaces are similarly found to use less fuel, in proportion to the work done in them, than furnaces of smaller size.

As to progress of invention of furnaces, see "The Furnace of the Future," in *Iron*, viii., 354.

For ovens, see BREAD AND BISCUIT MACHINERY. See also ASSAYING; BOILERS, STEAM; CHIMNEY; CRUCIBLE; ENGINES, STEAM, PORTABLE AND SEMI-PORTABLE; FURNACES, BLAST, CUPOLA, and METALLURGICAL; GAS, ILLUMINATING, APPARATUS FOR MANUFACTURE OF; GLASS-MAKING; IRON-MAKING PROCESSES; KILN; STEEL; and WARMING AND VENTILATION. See also the various lists of works for reference under metallurgical articles. The foregoing article is mainly abridged from a paper on furnaces by Mr. Hackney, for which see "Science Conferences, Special Loan Collection of Scientific Apparatus, South Kensington Museum," London, 1876.

FURNACES, BLAST. A blast furnace is a vertical structure in which ores of iron are reduced and smelted in contact with appropriate fuel and flux; the combustion of the fuel being accelerated by blast injected under pressure, and the height of the structure being such as to admit of a thorough admixture and preparation of the stock.

*Classification.*—Blast furnaces are classified according to the fuel employed, the heating of the blast, and the arrangement at the top or tunnel-head.

According to the fuel employed, they are known as—*a*, charcoal furnaces; *b*, coke furnaces; *c*, anthracite furnaces; *d*, raw (bituminous) coal furnaces; and the above order may be considered as representing the average superiority of the various fuels. Mixed fuels are often employed; thus,

wood or semi-charred wood or coke has been mixed with charcoal, and in some instances wood charcoal and peat charcoal are used. Coke is largely mixed with anthracite or with raw coal to increase the yield of furnaces.

Classified by heating of blast, the terms "hot-blast" and "cold-blast" are applied to furnaces. Cold-blast furnaces use charcoal exclusively, and their number is annually decreasing. In these the blast is injected into the furnace directly from the blowing apparatus. Hot-blast furnaces are those to which stoves or ovens are attached, and the blast is heated so as to intensify the combustion in the furnace. The term "warm-blast" has been applied to plants where the blast is moderately heated, say from 250° to 400° F. (120° to 210° C.). Since the introduction of the fire-brick hot-blast stoves, those employing a blast heated above 1000° F. (535° C.) have become known as using a *superheated blast*.

Classified as to the arrangement of the top or tunnel-head, furnaces are known as *open-top* or *closed-top*. The former either allow the gases a free escape from the tunnel-head, or draw them away by a superior draught through high chimneys. The latter employ some mechanical means of closing the top (except when charging stock into the furnaces), so as to more completely control the gases and convey them away in flues, generally known as *down-takes* or *down-comers*.

Structures.—The older furnaces are built of heavy stone masonry, pyramidal in form, inclosing the interior masonry, the lower portion being laid of sandstone, and the upper portion of soapstone or slate; sometimes ordinary bricks were employed. In Sweden some stacks are built of blocks made from furnace cinder, and instances are recorded where they have been used in the shaft of the furnace for lining.

1836.

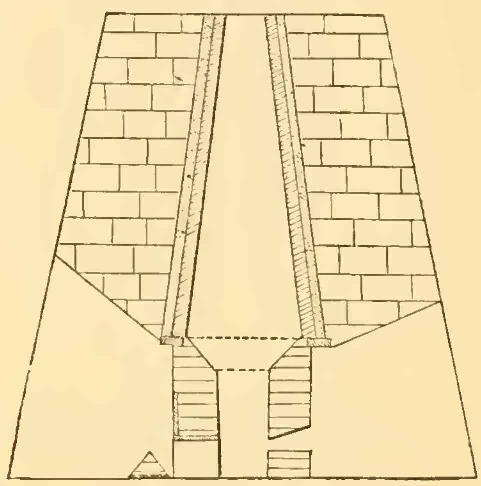


Fig. 1836 is a sectional view of an old charcoal furnace. *A* is the tunnel-head, 30 inches in diameter; *B*, the bosh, 8 feet in diameter; *C*, top of crucible or hearth, 3 feet square; *D*, bottom of crucible or hearth, 2 feet square; *E*, the tymp; *F*, the dam; *N*, the tuyere arch; *H*, the in-walls, of slate or soapstone. The masonry below *B*, of sandstone, constitutes the hearth and boshes.

These furnaces were generally located on hillsides, so that the stock could be delivered on a level with the tunnel-head and the iron tapped out at the bottom, the cinder being allowed to flow continuously over the dam *F*. They were generally placed convenient to a water-power, and the blast was injected through one open tuyere, being supplied from wooden blowing tubs operated by a water-wheel. If steam was used or the blast heated, the boilers or hot-blast stoves were placed on top of the structure, close to the tunnel-head, to permit of the employment of the waste gases.

There are instances of such furnaces now in operation, but the more modern are of different construction. They are either a shaft of heavy brick masonry, banded or caged with iron to prevent rupture, resting upon brick piers (see Fig. 1837), or upon iron columns and mantle-plate (see Figs. 1838 and 1850); or they are wrought-iron shells or casings inclosing light masonry supported upon iron columns and mantle-plates. The walls of the crucible and boshes, being exposed, are strengthened by buck-staves and binders (see Figs. 1839, 1851, 1852, and 1856). In many cases water-jackets encircle the crucible, to keep it at a low temperature and prevent the rapid destruction of the refractory linings. The bottom and all the walls are of fire-brick laid in refractory clay. Blocks from 3 to 6 inches thick and 12 to 24 inches long are ordinarily employed, but sometimes no special shapes are used, and furnaces are lined throughout with 9-inch fire-brick. For bottoms, blocks of fire-clay are laid on end; and various shapes have been made to prevent the blocks from lifting, by constructing them in a series of wedges, or forming offsets and recesses upon them. Bottoms are also made of large sandstones neatly jointed, and monolithic bottoms formed of fire-clay well rammed and dried are in use. Fig. 1839 illustrates one form of doubled-wedged bottom blocks, resting on a layer of fire-clay below which is sand.

Small furnaces are blown with 2 or 3 tuyeres; and as many as 16 tuyeres have been inserted in one large furnace, by placing them in two tiers. This, however, does not meet with general approval at present. Some large furnaces use only 4 tuyeres, but the greater number employ from 5 to 8.

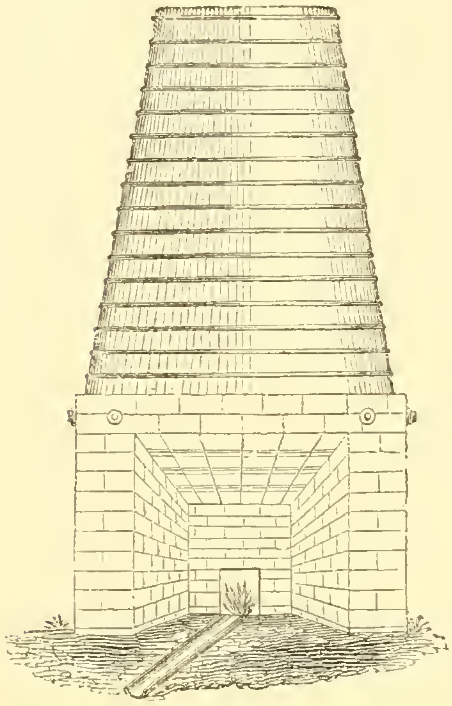
The sizes of furnaces have ordinarily been compared by the diameter at bosh, 8 to 11 feet being considered as small, 12 to 16 feet as of medium size; and the large furnaces are those having a greater diameter at bosh than 16 feet. Latterly, however, since the height of a furnace has been considered such an important factor in its operation, a more appropriate comparison is made as to the cubic feet of capacities. The diameters of the boshes of existing furnaces are from 8 to 30 feet, and the heights from 25 to 103 feet, the cubical contents varying from about 1,000 to over 40,000 cubic feet. Most furnaces, however (exclusive of those using charcoal), are included within the range of 13 to 20 feet diameter of bosh, 40 to 80 feet height, and 3,000 to 20,000 cubic feet capacity.

Shape of Furnaces.—The proportions of a furnace seriously affect its operation, and instances can be found of furnaces of equal diameter of bosh and nearly equal capacity, using practically the same stock, and other circumstances being similar, whose weekly outputs are as 1 to 2; much of which is directly traceable to the proportions. Attempts have been made to establish universal formulæ for blast-furnace proportions; but they are useful only so far as they indicate certain limits of possibilities, and they must be decidedly elastic to provide for the behavior of the various fuels and ores employed or the character of product desired.

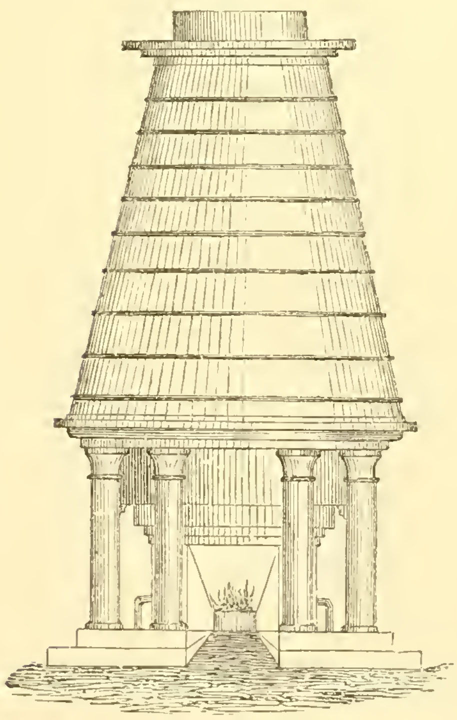
The typical form of blast furnace consists of two frusta of cones placed base to base and resting upon a short cylinder. The upper frustum forms the shaft of the furnace, the lower frustum the boshes, and the cylinder the crucible or hearth. Such forms are shown in Figs. 1836 and 1850. Curves are employed in lieu of straight lines and sharp angles in some furnaces, or a combination of curves and straight lines, as in Fig. 1839; but the relative proportions of the various parts of the furnace are of much greater importance than the presence of angles or curves.

All furnaces may be considered as being divided into four zones, as follows: *a.* The zone of preparation is that portion of the furnace included between the stock-line (i. e., the point at which the stock is distributed when charged into the furnace) and the bosh, or greatest diameter. *b.* The zone

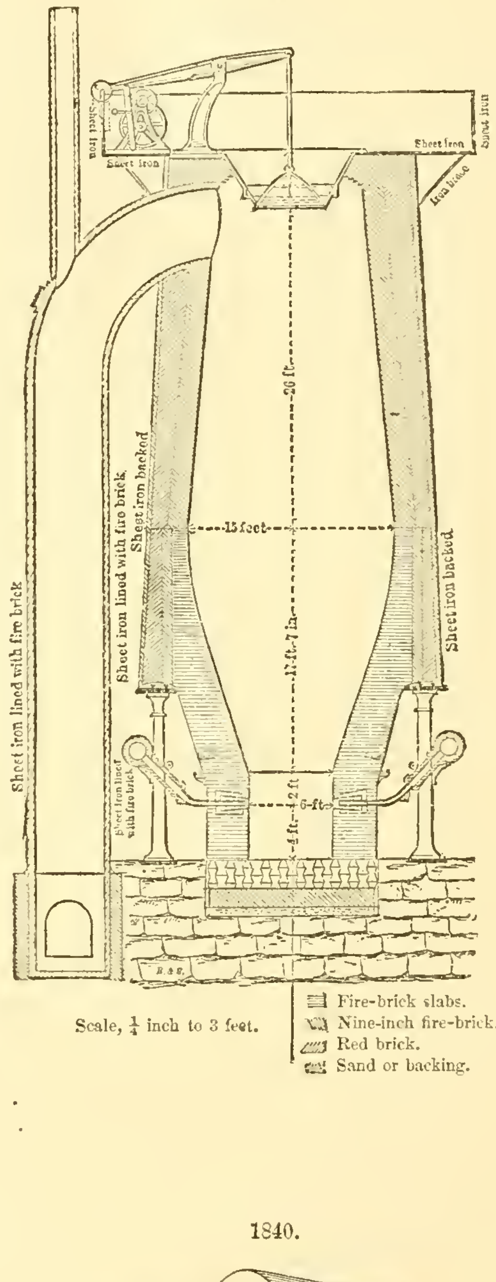
1837.



1838.



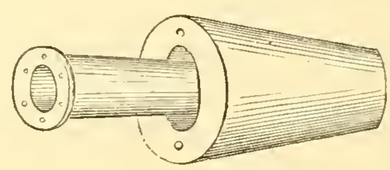
1839.




Scale, $\frac{1}{4}$ inch to 3 feet.

Fire-brick slabs.
Nine-inch fire-brick.
Red brick.
Sand or backing.

1840.



of reduction extends from the bosh to a plane 3 or 4 feet above the tuyeres. *c.* The zone of fusion includes the portion of the furnace from the bottom of the zone of reduction to the level of tuyeres. *d.* The *well* is that part of the crucible which is below the tuyeres, and in which the molten iron and slag is caught and retained in a murtex of fuel. The relative proportions of these zones are influenced by the character of ores and fuel employed, the product desired, and the intensity of blast. To obtain good results, the upper zone should be of such height and capacity as to thoroughly incorporate and prepare the stock for the middle zone, by driving off vapors and volatile matter and partially deoxidizing them. In the middle zone complete reduction and deoxidation should result, and the material be delivered in proper quantity to the zone of fusion, whose size must depend upon

the work to be done and the condition of the blast. The capacity of the zone of preparation depends upon the relation of stock-line to bosh and the distance between them. The *drive* of the furnace, or its rapidity of reducing and smelting ores, is affected by the slope of boshes, which generally approximates 70° from a horizontal line. The boundaries of the zones being imaginary planes, they will vary greatly in different furnaces, and in the same furnace will be affected by the operation at different times. The division as given above is used in designing a furnace and adapting it to the ores to be employed and the product desired.

Yield of Furnaces.—In comparing the output of different furnaces, the amount of iron made per week is the generally accepted basis, and the designation of a plant as a 100-ton, 200-ton, or 300-ton furnace would indicate that the capacity is that number of tons per week. The gross ton (2,240 lbs.) is the standard of weight, and, except when cast into iron chills for mill purposes, an allowance of 14 to 30 lbs. for sand is made. A furnace of a given capacity and of appropriate construction and management will give a greater yield with charcoal than with any other fuel, and consume less fuel per ton of iron. Other fuels rank in the order before named, viz.: coke, anthracite coal, bituminous coal.

The variations of stock and management, and arrangement of details, affect the amount of product, and there is therefore considerable difference in the output of the same sized furnaces; but by taking an average the following will be found closely to approximate actual practice. The weekly output of a cold-blast charcoal furnace in tons of pig-iron is equivalent to 45 per cent. of the square of the diameter at bosh in feet. The weekly output of a hot-blast charcoal furnace is equivalent to 95 per cent. of the square of the diameter at bosh in feet. Thus, a 9-foot furnace would make 95 per cent. of $9 \times 9 = 77$ tons per week. Superior ores and efficient management have in several instances increased the output per week for a continuous blast to 250 per cent. of the square of the greatest diameter, and contrary circumstances reduced the product. The average weekly yield of a coke furnace in tons is about 85 per cent. of the square of the diameter of the bosh in feet; but in some of the large furnaces the output has amounted to 200 per cent. The anthracite and raw-coal furnaces approximate 80 per cent. of the square of the bosh; but at Pottstown, Pa., a 16-foot anthracite furnace has yielded 385 tons of metal per week, equivalent to 150 per cent. of the square of the bosh.

Consumption of Fuel.—To produce one ton (2,240 lbs.) of pig iron, the following weights of different fuels are consumed:

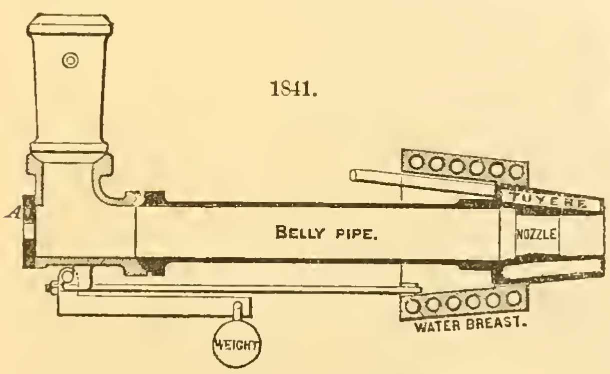
| | Minimum. | Average. |
|---|---|---|
| Charcoal | 1,360 lbs. | 2,500 lbs. |
| Coke | 2,025 " | 3,000 " |
| Anthracite | 2,460 " | 3,300 " |
| Raw coal | 3,000 " | 4,000 " |

The minima given above are the lowest recorded consumption of fuels, and are only attained under exceptionally favorable circumstances. The percentage of iron in the ore used obviously has a decided influence upon the yield of various furnaces, and the consumption of fuel per ton of iron; and in comparing the output and fuel consumption of various furnaces, the richness and chemical composition of the ores employed must be considered.

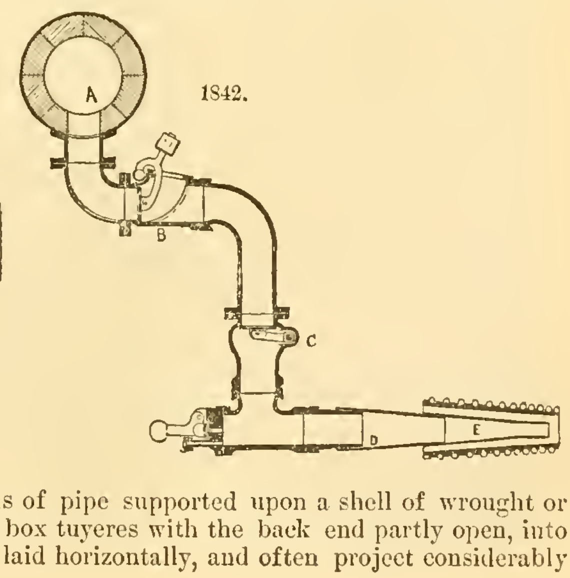
Fixtures.—In place of the old method of constructing the dam some distance in front of the furnace walls, the dam is now set up to the crucible walls, and the long fore-hearth dispensed with; the tymp is set in a recess in the walls; and both dam and tymp are kept cool by coils of pipe in them, they being cast about the pipe to appropriate pattern; an iron notch or tapping-hole is provided in the dam. When the tymp is placed above and back of the dam, thus leaving an opening for reaching into the furnace with shovels, etc., the term "open front" is used; but where the cinder notch consists of a water-cooled block similar to a tuyere, the title "closed front" is applied.

*Tuyeres* are of various kinds, viz.: the box tuyere (see Fig. 1840), a hollow conical case closed at both ends, into which water is allowed to flow at the bottom and escape at the top; the coil tuyere, a conical coil of pipe through which water circulates; cast-coil tuyeres, coils of pipe about which a

1841.

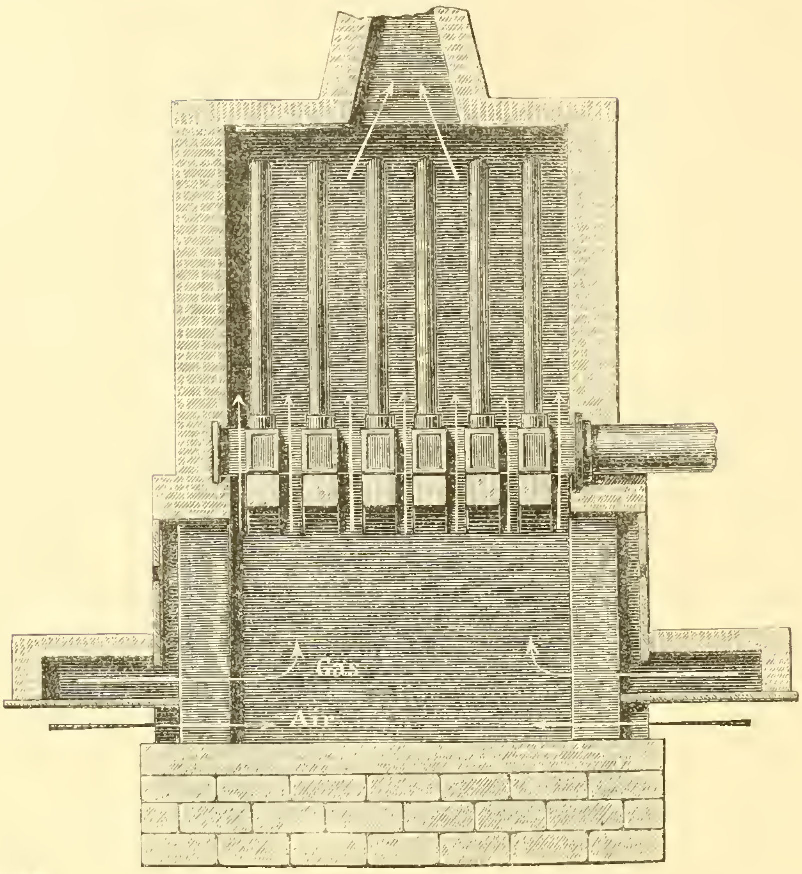



1842.

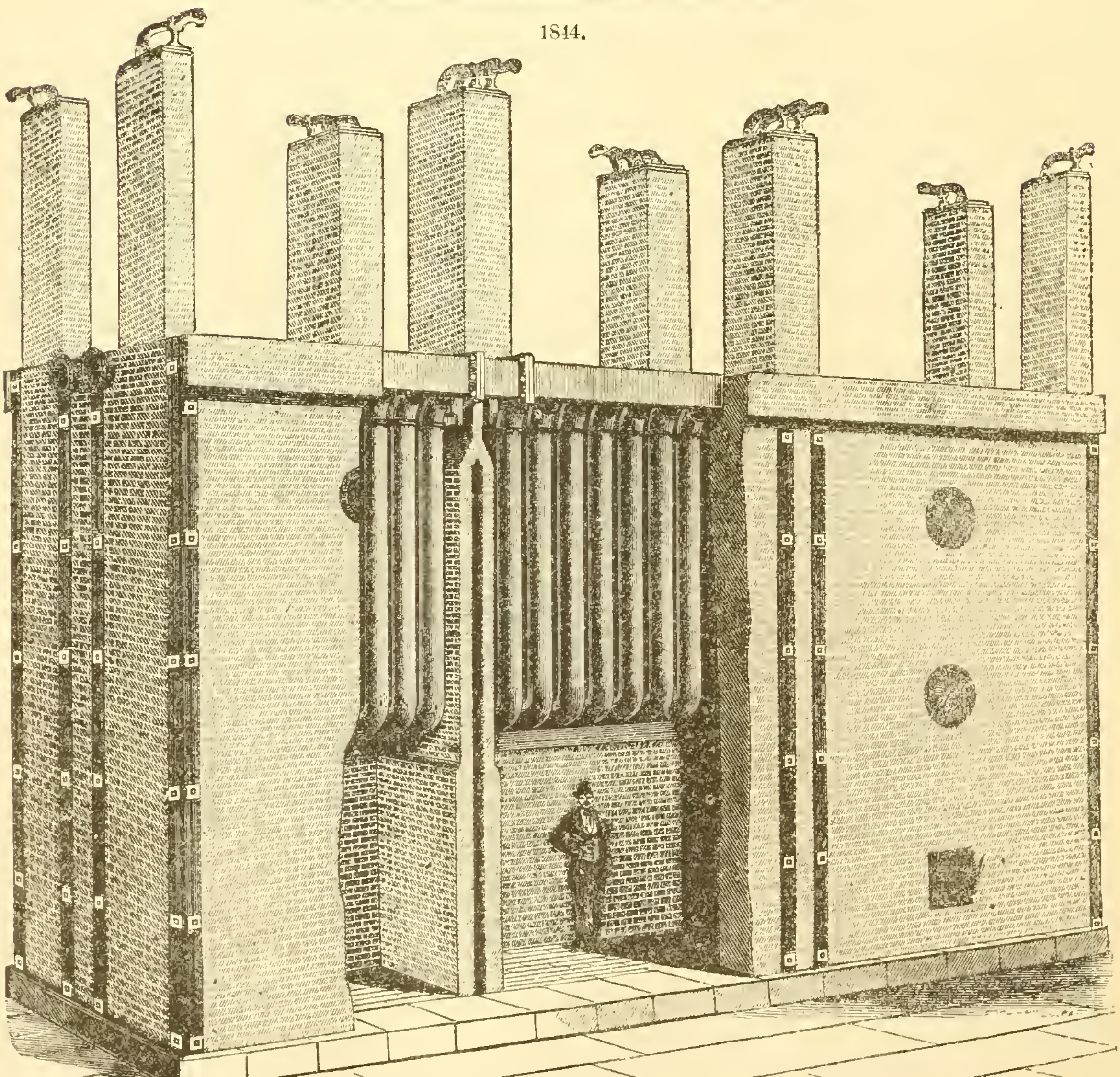



conical casting has been run; shell-coil tuyeres, coils of pipe supported upon a shell of wrought or cast iron, but independent of it; and spray tuyeres, box tuyeres with the back end partly open, into which perforated water-pipes project. Tuyeres are laid horizontally, and often project considerably

1843.




1844.



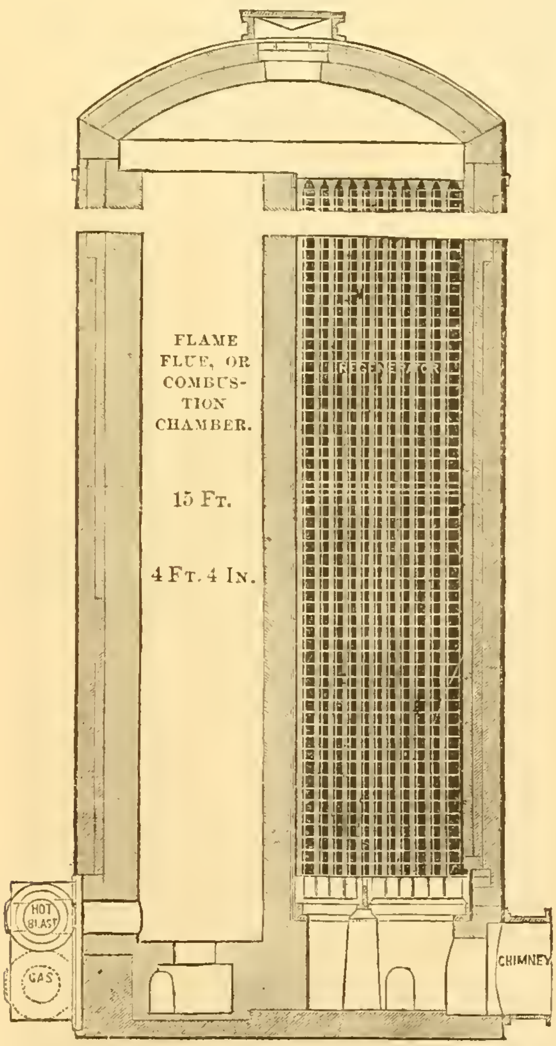
into the crucible of the furnace; they are made of iron or of bronze metal. The pipe which conveys the blast into the tuyere is known as the belly-pipe. It is projected partially or entirely into the tuyere, and the diameter of the opening of the small end or nozzle usually determines the volume of blast. The other end of the belly-pipe is connected on to a bend, in which a sight-hole or pricker-hole is placed, so that the condition of the interior of the furnace can be judged by inspecting it through the belly-pipe. This also gives a means of cleaning scoriæ from the nozzle or tuyere by means of long pricker rods.

The perforations through the crucible walls into which the tuyeres are inserted are arched with fire-brick, and in many instances water-cooled arches, or *water-breasts* as they are termed, are inserted. The space between the tuyere and the breast is packed with clay. Fig. 1841 shows an arrangement of short box tuyere, water-breast, belly-pipe, etc., in which the tuyere snugly fits the breast and requires no packing, and a series of weights and levers are substituted for the usual key-bolts to facilitate the removal of the tuyere or change of the size of nozzle.

The blast, after leaving the blowing apparatus, is ordinarily carried into a large vessel or receiver, and from this a connection is made to the hot-blast stoves. A safety-valve and also an escape-valve, controllable from the front of the furnace, are placed in this connection. The hot-blast stoves are placed as close as possible to the furnace, and the heated air is led through a protected bustle-pipe or circle-pipe, from which connections are made to each tuyere. In these connections blast-checks are placed, so that when the blast is slackened the valves close and permit of gases escaping into the air, thus preventing explosions in hot-blast stoves, etc. It is also advisable to employ a valve for each tuyere, to be closed by hand, so that any one can be removed at will. Fig. 1842 illustrates a modern arrangement of a shell-coil tuyere $E$, belly-pipe $D$, stop-valve $C$, blast-check $B$, and blast-pipe $A$, the tuyere fixtures being held in place by key-bolts.

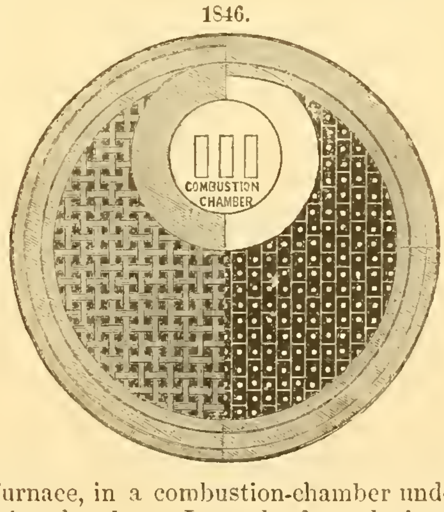
The Hot Blast.—A retrospect of the growth of the production of pig iron in the past half century would be comprised in the invention and introduction of heated blast as applied to iron-smelting. To compare the original iron box heated over a coal fire, as employed by Neilson, with the modern blast-heating apparatus, with improved combustion-chambers, gas-burners, air-regulators, etc., would be equivalent to comparing the yield of the little *Blauöfen* with the improved furnace of to-day. It is only lately, however, that the true value of the hot blast has been appreciated, it having been considered simply as a means of increasing the product of a furnace, and its value as a method of controlling the operation overlooked.

1845.




There are three typical forms of hot-blast ovens, viz.: standing-pipe, suspended-pipe, and fire-brick stoves. Of the first there is a large number of styles, but they all agree in consisting of bed pipes into which vertical pipes are placed. The general arrangement consists of U-pipes inverted, the blast passing up one leg and down the other, and being heated by the combustion of the waste gases from the furnace, in a combustion-chamber underneath the pipe-chamber. Instead of employing inverted U-pipe, single pipes divided by diaphragms, or double pipes, i. e., one pipe within another, are used to a limited extent. Fig. 1843 illustrates a simple form of standing-pipe hot-blast stove. The suspended-pipe stoves differ from those just described in having the pipe hung from the top. U-pipes are employed, and the advantages claimed are greater life of pipes, compact structure, and ease of making repairs. Fig. 1844 represents a Weimer suspended-pipe stove, consisting of six chambers, each containing eight U-pipes. The standing pipe and suspended pipe are both placed in fire-brick chambers.

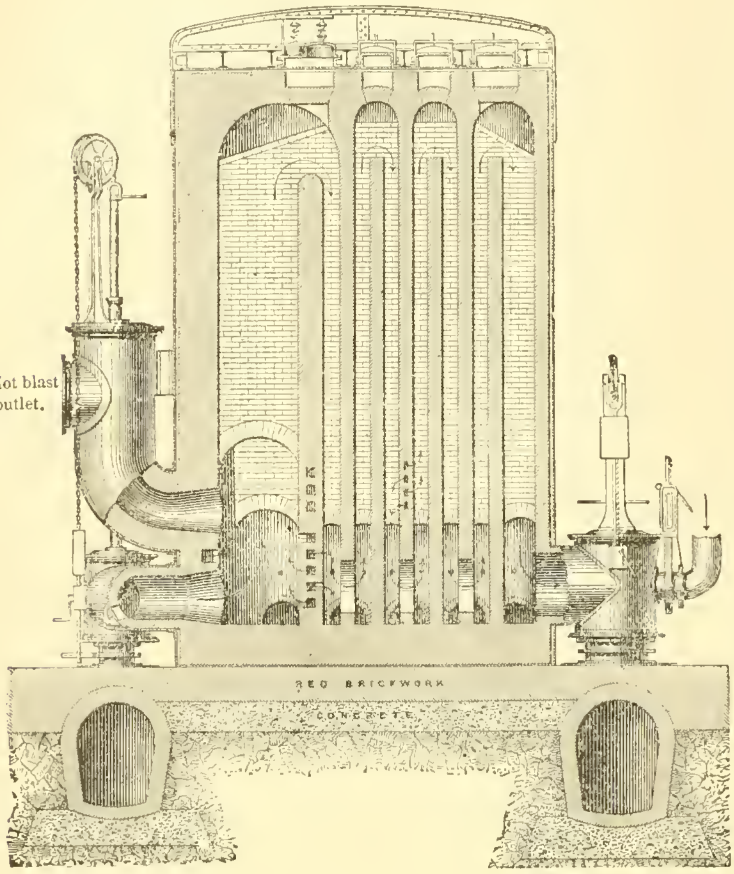
1846.




The third class of stove in use is what is known as the fire-brick or regenerative stove, of which there are two forms. It is necessary that two or more of these stoves should be used, for the essen-

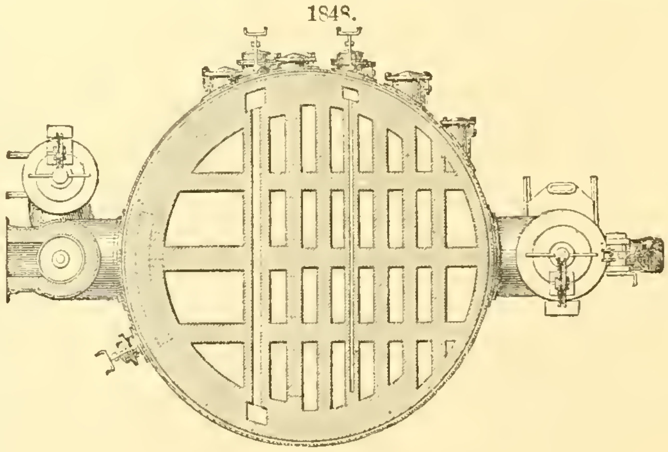
tial principle of their operation is that each stove is a mass of fire-brick, which attains a high temperature by the combustion of furnace gases, and gives off its heat to the air afterward driven through it. As the stove must first be heated up and then impart its heat to the blast, some of the stoves must be receiving their heat while the others are heating the blast. To prevent too great variations of temperature, not less than three stoves should be used. Figs. 1845 and 1846 represent vertical and horizontal sections of a Siemens-Cowper-Cochrane stove, consisting of a vertical combustion-chamber, and a mass of checkerwork made of fire-brick to expose as great heating surface as possible. The masonry is inclosed in a sheet-iron jacket. Figs. 1847 and 1848 are vertical and horizontal sections of a Whitwell stove. The essential difference between this and the preceding stove is the use of a series of walls built of fire-brick, which the blast traverses to obtain its heat. The regenerative principle is the same in either stove. The advantages claimed for regenerative stoves are that more intense heats are possible than with cast-iron pipe, there is less liability to damage by the heat, and an economy of fuel is possible. Except in special instances, however, there has been no decided advantage shown to result from a steady work at a temperature above what is possible with iron-pipe stoves. One especial value of regenerative stoves is their capacity as reservoirs of heat, which can be used often to great advantage to help a furnace out of "trouble" or bad working.

1847.



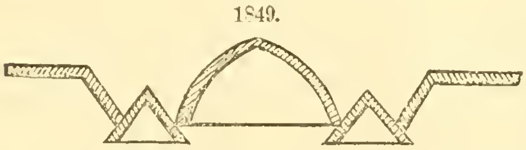

Bell and Hopper.—There are a number of furnaces which are still known as "open-top," but much the larger number are provided with a "bell and hopper" or "cup and cone." The ordinary forms are exhibited in Figs. 1856, 1850, and 1851. The hopper is a cup-shaped casting, having a projecting flange which rests upon the masonry of the furnace, the aperture below being somewhat smaller than the diameter of the bell, which is a conical casting suspended at the apex from an operating beam, as in Fig. 1851. An improvement is shown in Fig. 1839, where the aperture in the hopper is of greater diameter than the bell, and there is an offset or shoulder to receive a lip-ring which forms the lower portion of the hopper. The advantages of this arrangement are, that it is not necessary to remove the hopper when a bell is taken out, and severe explosions are less liable to move the hopper. The purposes of the bell and hopper are to close the top and force the gases down the flues provided for them, and also to distribute properly the stock charged upon the bell. The size of the bell therefore has a direct relation to the stock-line. Various forms have been employed to accomplish proper distribution. Among others is a double bell, Fig. 1849, in which the centre cone does not drop, but a conical ring closes against it and the hopper. When this ring is lowered, the supposition is that the stock is equally distributed over the throat of the furnace. A similar arrangement is employed with the central flue mentioned below. In the usual arrangement, when the bell is lowered, the gases from the furnace have a free escape, and are drawn away from the boilers and hot-blast stoves. To prevent delay in operating the bell, the lever is moved by a hand-winch or by steam or compressed air. A cover for the tunnel-head is also perfected, in which are openings for dumping charges, provided with sliding covers. These openings are closed before dropping the bell, and opened when the bell is closed; loss of gases is therefore

1848.



PLAN IN SECTION.

1849.

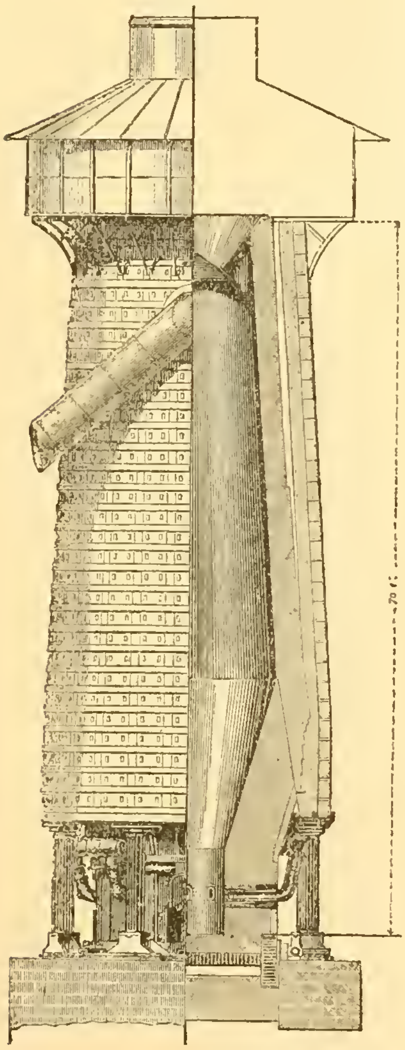


prevented. To accomplish the same result and insure more thorough distribution of the stock, the hopper is placed several feet below the top of the furnace, so that the charge of stock when dumped from the charging-barrow strikes on the apex of the bell, falling equally upon all sides. When the charge is ready to be lowered, the tunnel-head is covered by a plate suspended from a beam, which is removed after the bell is again raised to position. In both cases the covers are operated by steam or compressed air. In some open-top furnaces, a bell is hung in the throat of the furnace to insure distribution of the stock.

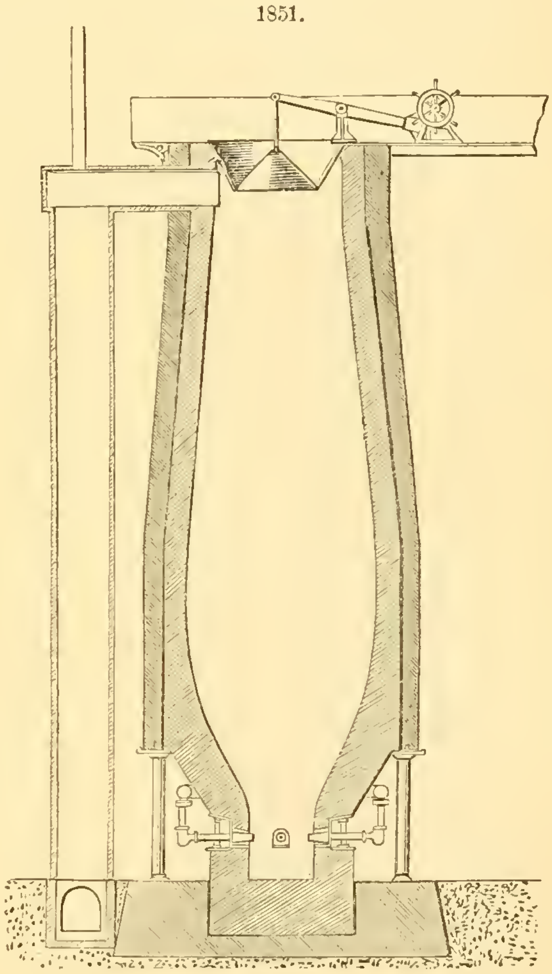
Gas Flues.—The gases are taken off below the bell by flues, and in modern plants carried to the ground in down-comers, which are wrought-iron tubes, usually lined with fire-brick. These are sometimes of considerable size, even in furnaces of moderate dimensions, and in many large furnaces are out of proportion to everything else. Some down-comers are of sufficient capacity to convey five times the quantity of gas which is ever made in the furnace.

The flues into the furnace are ordinarily circular or arched horizontal openings above the stock-

1850.



1851.



line, but in open-top furnaces they are often narrow vertical slits below the stock-line, with an upward inclination.

The central flue above mentioned is sometimes used. This is a vertical wrought-iron pipe, extending from below the stock-line up through the tunnel-head, and then passing off to the side of the furnace and thence to the down-comers. The draught from a tall chimney and the stock packed around the outside of the flue cause the gases to pass through this central flue.

The connection from the down-comer to the hot-blast stoves and boilers is either by wrought-iron flues above ground or by masonry underground flues; and they usually terminate in gas-burners, by which the supply of gas and of air can be regulated.

Boilers.—Long horizontal-cylinder boilers, either set singly or *two high* and placed in nests, are most in favor with furnacemen. Flue and tubular boilers require more attention, on account of the amount of dust which accumulates unless the gases are washed previous to burning them. The ordinary furnace steam-pressure is 50 to 70 lbs. per square inch.

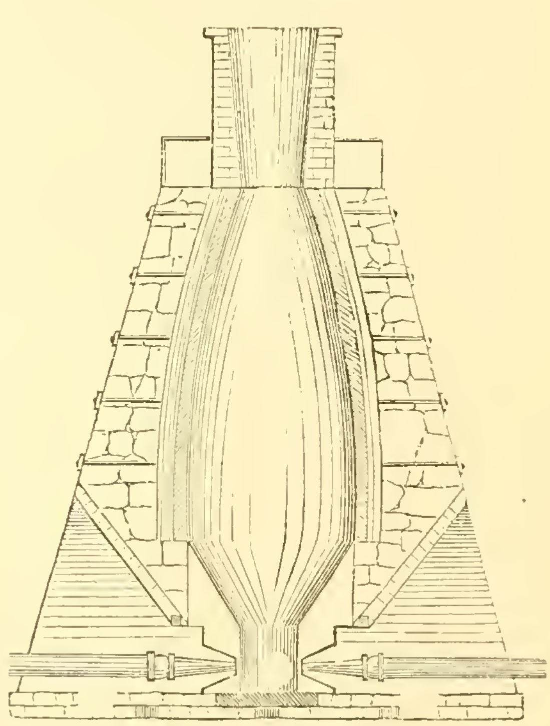
Blowing Apparatus.—As the supply of gases is seldom insufficient for both boilers and hot-blast stoves, water-power is not employed except at the older charcoal furnaces. Steam blowing engines are chiefly used, and there is quite a variety of them, including horizontal engines working direct or operated from a steam-engine by gearing, vertical blowing-tubs driven by a horizontal engine, vertical bull engines, and vertical beam engines. The present demand is for vertical bull engines, or those having a single steam-cylinder placed under a single blowing cylinder supported on housings

or columns, the steam and blowing pistons being secured to the same rod, as a horizontal cross-head which carries connecting-rods for two fly-wheels. Puppet-valves are largely employed. The pressure blown is from three-fourths of a pound to 3 lbs. for charcoal, 3 to 7 lbs. for coke, 4 to 14 lbs. for anthracite, and 2 to 6 lbs. for raw bituminous coal. The best practice now favors running by the volume of blast rather than by the pressure, and small high-speed engines are in many cases displacing the more massive engines of slower motion. There is no fixed rule among furnace managers for the amount of air supplied to various furnaces; from data collected at a number of furnaces, the amount of blast varied from less than 200,000 to over 500,000 cubic feet per ton of pig iron, and from 77 to 165 cubic feet per pound of fuel consumed. In every case the number of cubic feet of air supplied per minute was greater than the cubic feet capacity of the furnace, the average being as 17 to 10.

Charges.—A *charge* or *round* is a specified amount of fuel (generally a barrow of charcoal or a net ton of other fuel) and the proportionate amount of ore and flux, which is termed the *burden*. Thus a charge for a charcoal furnace would be a barrow (20 bushels) of charcoal, 1,000 lbs. of ore, and 60 lbs. of limestone. The furnace would be then working on 1,000 lbs. burden, and carry 6 per cent. of flux. Or an anthracite furnace would charge 2,000 lbs. of coal, 3,600 lbs. of ore, and 1,980 lbs. of limestone; its burden would be 3,600, carrying 55 per cent. of flux. The number of charges or rounds in 24 hours indicates the drive of furnaces. Sometimes much larger quantities of fuel than

1852.

1853.



2,000 lbs. are used as a basis for the charge. A locked scale, balanced to the weight of barrows and provided with a series of levers for fuel, ores, and flux, is generally employed to weigh the charges.

The time occupied in the passage of stock through the furnace will average nearly 48 hours, but it is in some plants 80 hours; and charcoal furnaces have driven so fast that the stock has not remained in them over 8 hours. This applies to absolute working; for when for any cause a furnace is stopped for any length of time, the manager either "blows out" or banks up. In the former case he endeavors to get everything out of the furnace, and in the latter to keep all in by charging extra fuel and closing all draughts. In this manner stock may remain in a stack for a long time.

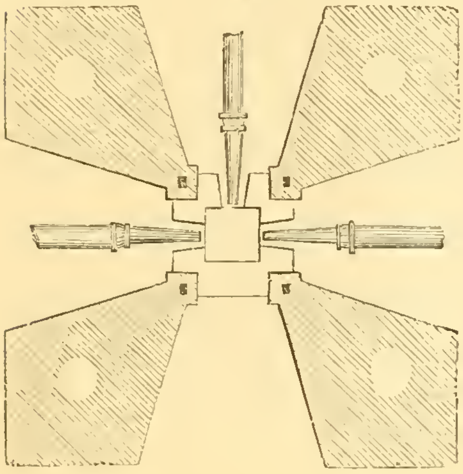
Hoists.—The old mode of constructing furnaces on a steep hillside, so as to conveniently deliver the raw materials at the level of the tunnel-head, and convey the pig iron and slag away from the fore part, has given place to plants erected upon flat or sloping ground convenient to railroads. In these the raw materials are raised to the level of the tunnel-head by vertical hoists or inclined planes, considerable ingenuity being displayed in the arrangement of the various parts. The compressed air produced by the blowing apparatus is often employed for operating the hoist. Hydraulic hoists and water-balanced lifts are used to a limited extent, but the greater number of furnaces use steam as the power.

The illustrations herein given represent the various styles of furnace construction employed. Fig. 1839 is a section of a raw bituminous coal furnace in Ohio, with curved boshes and straight in-walls, and is supported on columns and encased with a sheet-iron jacket. It is 15 feet in diameter at bosh and 50 feet high; crucible, 7 feet diameter, pierced for 7 tuyeres.

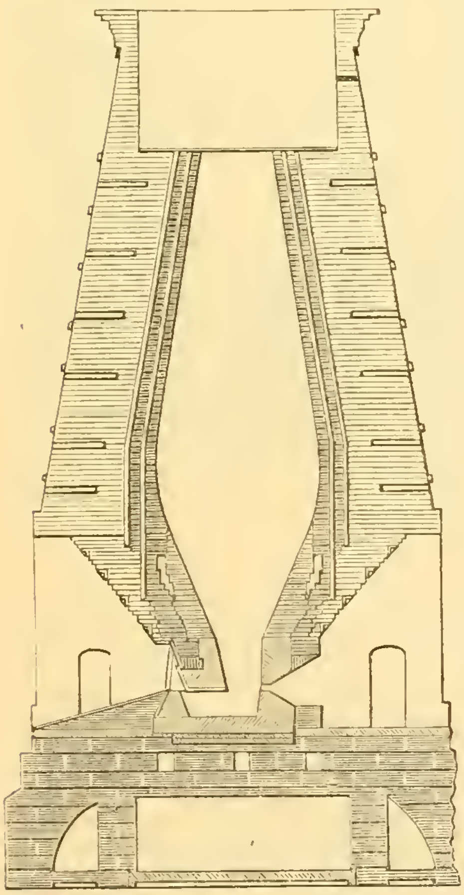
Fig. 1850 is a half elevation and half section of an anthracite furnace at Bethlehem, Pa. It is supported on columns, and the brickwork is caged with staves and bands of iron. It is 17 feet in diameter at bosh and 70 feet high; the crucible is 7 feet 6 inches in diameter, and blast is supplied by 5 tuyeres. The section is of straight lines and angles.

Figs. 1851 and 1852 exhibit the section and elevation of a coke and anthracite furnace at Chicago;

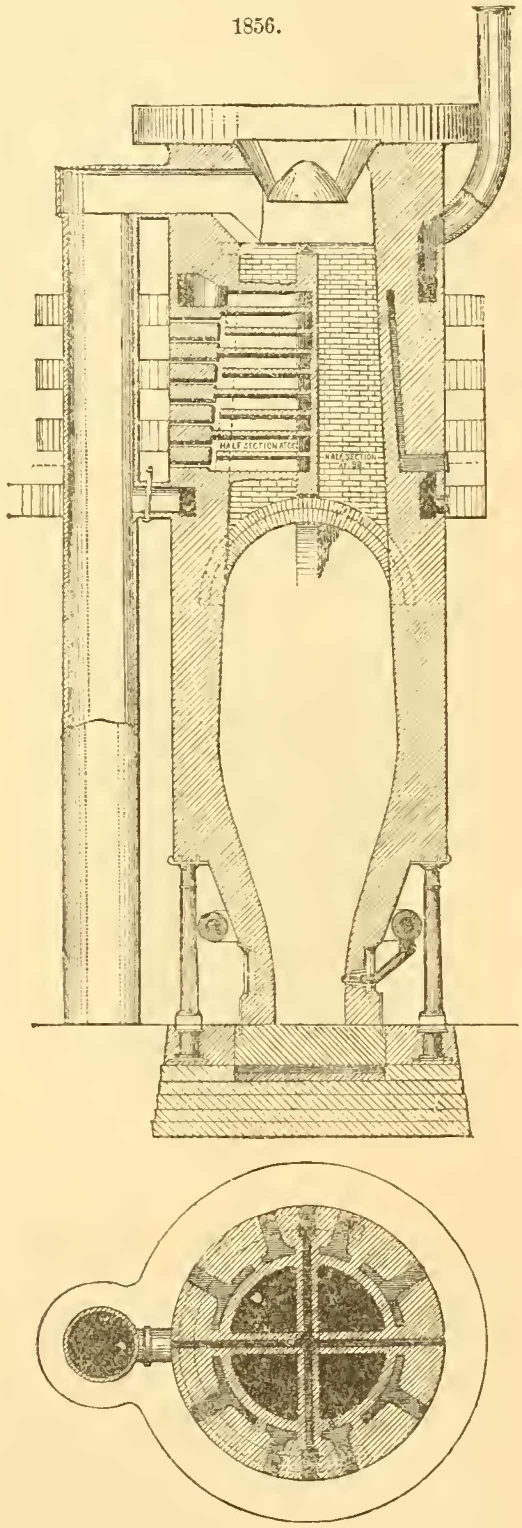
1854.



1855.



1856.



the section is entirely of curved lines. The bosh is 17 feet in diameter; the height is 66 feet. The crucible is 6 feet in diameter, and is blown by 4 tuyeres.

Figs. 1853 and 1854 illustrate the construction of an old-style blast furnace.

Fig. 1855 is a vertical section of a German furnace.

The above fairly illustrate the variations in style and proportions, but there are many modifications of shape or details.

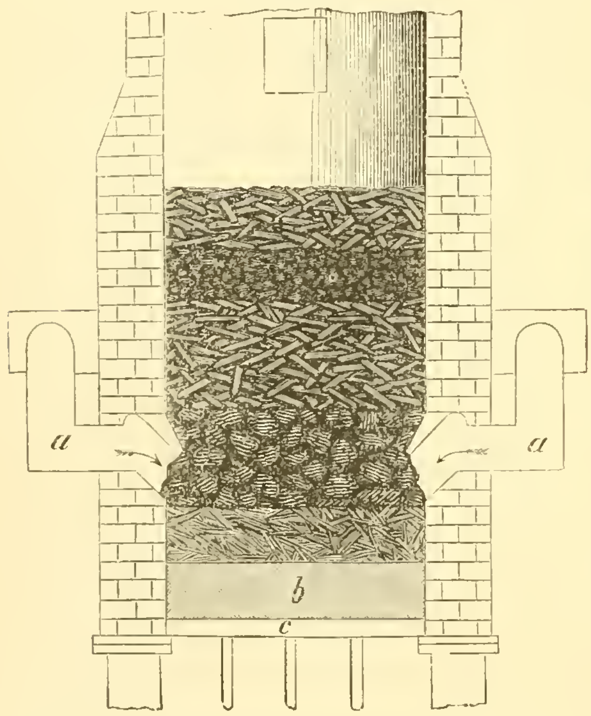
Efforts have been made to get more intense combustion by injecting petroleum, and considerable attention has been given to the calcination of the stock in high furnaces. The most prominent instance of this is the Ferrie self-coking furnace shown in Fig. 1856, used in Scotland and to a slight extent elsewhere. The upper portion of the furnace is divided into chambers or retorts, the cross and side walls containing flues in which part of the gases from the furnace are burned. The raw

coal, ore, and flux are charged into these chambers, and the heat generated by the combustion of the gases (controllable by air-valves) cokes the coal, roasts the ore, and prepares the flux for action in the furnace proper below. This illustration shows a water-jacket surrounding the crucible, water-breasts, plain tuyere fixture, and lined bustle-pipe and down-comer.

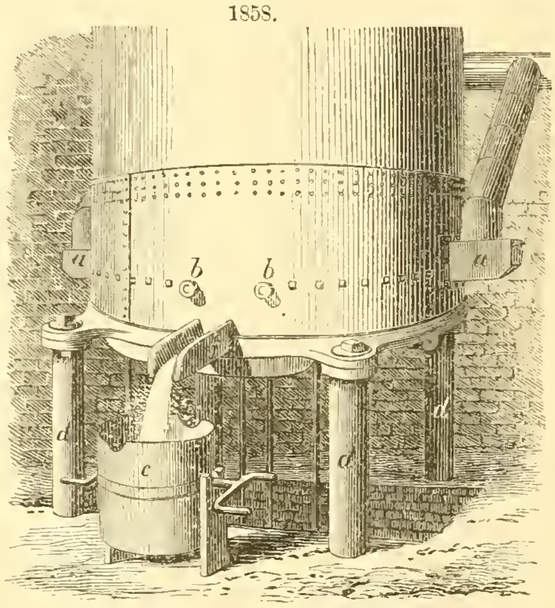
*Works for Reference.*—"Iron and Steel Manufacture," Kohn, London, 1868; "Metallurgy of Iron and Steel," Osborn, London, 1869; "Researches on the Action of the Blast Furnace," Schintz, London, 1870; "Iron and Heat," Armour, London, 1871; "Chemical Phenomena of Iron-Smelting," Bell, London and New York, 1872; "Guide to the Iron Trade of Great Britain," Griffiths, London, 1873; Wiley's "Iron Trade Manual," New York, 1874; "Studies of Blast-Furnace Phenomena," Gruner, Philadelphia, 1874; "Metallurgy of Iron," Bauerman, London, 1874; "Metallurgy of Iron and Steel," Percy, London, 1875. For descriptions of the most recent advances, the reader is especially referred to the files of *Iron*, *Journal of the Iron and Steel Institute*, *Engineering* (see series of papers on "American Iron and Steel Works," by Holley and Smith, vol. xxv.), *Engineer*, *Iron Age*, *American Manufacturer*, and *Engineering and Mining Journal*. J. B.

FURNACES, CUPOLA. Furnaces for melting metals prior to casting. In modern practice the cupola is usually made of boiler-iron in the form of a cylinder or cylindroid, lined with fire-brick. It is from 10 to 16 feet in height and from 3 to 6 feet in diameter inside, and capable of melting from 5 to 15 tons of metal per hour. The chimney may be of brick, or of boiler-iron lined with fire-brick, which is more common. A cupola is often spoken of as holding a charge of so many tons of metal; but as only a limited quantity of molten metal can be contained in it at one time, its capacity is more correctly measured by the amount of metal it will melt in a given time. Fig. 1857 is a perpendicular section of a cupola, to enable the reader to understand the manipulations connected

1857.




1858.

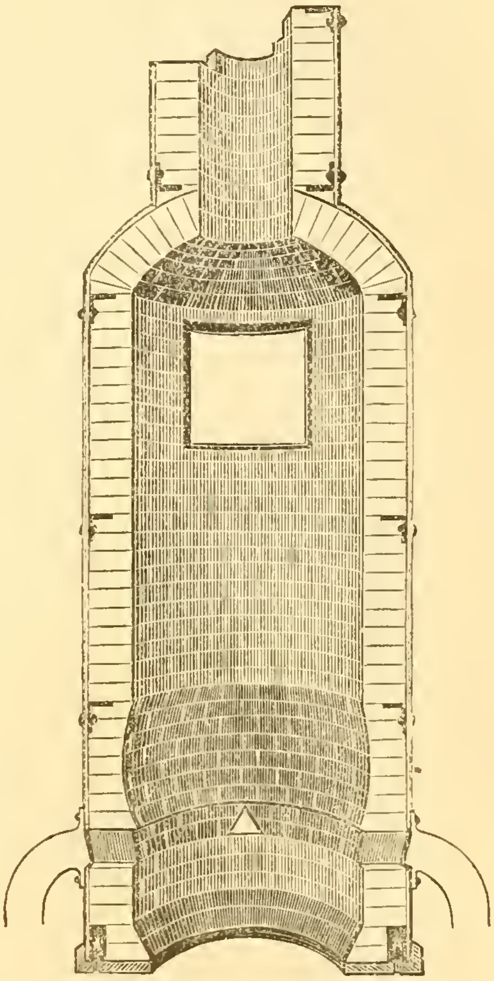



with the process of casting. The tuyeres, *a a*, are seen to enter the cupola from 10 to 16 inches above its floor. The space just above the tuyeres has the shape of an inverted cone, which has the effect to hold the contents in such a relation to the blast as is best calculated to make it the most effectual. The floor of the cupola, *b*, when in use, is composed of sand 6 or 8 inches in depth, lying upon the bottom plate *c*, which rests upon supports, and may be dumped by their removal. Some cupolas are chambered at the lower section, the blast entering through a row of holes in the inner wall. In the upper part of the back of the cupola is the door for receiving the charges. Fig. 1858 shows the exterior of the lower part of a cupola: *a a*, tuyeres; *b b*, small isinglass windows for showing the state of combustion and position of the layer of coal; *c*, pot for receiving the melted metal; *d d*, columns of support. (The smaller upright rods support the movable floor, and stand in the pit below the cupola.) A cupola is charged by placing a sufficient quantity of kindling-wood upon the floor, and above this a layer of the best anthracite coal in large lumps, and in sufficient quantity to fill the cupola to the height of several inches above the entrance of the tuyeres after it has well settled and the wood has burned away. This precaution must be carefully observed, because if the charge of iron above the coal should come down to a level with the entrance of the blast, combustion would be checked, the metal become chilled, the process stopped, and the dumping of the charge necessitated. Upon the layer of coal thus carefully deposited, one of pig-iron is placed, varying in quantity from 1,000 to 5,000 lbs., according to the size of the cupola and to the rapidity with which it is proposed to effect the melting; and upon this another layer of coal is deposited, and afterward succeeding layers of iron and coal. Fluxes are added where occasion requires, according to the judgment of the founder, pounded marble or limestone being most frequently employed. The wood is usually ignited when the first layer of coal is deposited, and in from an hour to an hour and a half the furnace may be tapped.

In Fig. 1859 is represented an improved cupola for melting iron, highly recommended by Mr. Edward Kirk in his "Founding of Metals," from which work we take the following description:

"The bottom plate should project inside of the lining in a large cupola, so as to make the bottom doors smaller and easier to handle; and the lining should be sloped out to the edge of the bottom plate, so that the sand bottom will all fall out when the iron bottom is dropped. This offset also helps to support the stock, and takes part of the weight off of the iron bottom. The caisson or shell of a cupola will often rust off, and give way around the bottom. This is caused by the lining sweating and the moisture settling to the bottom, and by putting in a heavy sand bottom, and providing no way for the moisture in the sand to escape; this moisture keeps the lower courses of brick always damp, and causes the caisson to rust off in a short time. The illustration shows how this may be avoided by laying the first two courses of brick out one or two inches from the caisson, so as to form a small air-chamber all around the cupola, as represented by the letters *A A*. Small holes should be put in around the bottom of the caisson, or through the bottom plate, to supply this chamber with fresh air, and allow the moisture to escape. A triangular-shaped tuyere is the best, especially for a small cupola; for it comes up to a sharp point at the top, and is not nearly so liable to bridge over as the round or oval-shaped tuyere. There is a hollow place in the lining of this cupola, just above the tuyeres, which indicates the melting point of the cupola. If a cupola is lined up straight, it will burn out hollow at this point in one or two heats; and in daubing up the cupola for a heat, it should never be daubed up straight or too full at this point, but should be left a little hollow, as shown in Fig. 1859. Brackets or angle-iron should be riveted on to the caisson every three or four feet, so as to support the lining, and admit of the lower part, where the lining burns out the fastest, being taken out and replaced without taking down the whole lining. The lining can be taken out and replaced without the brackets by taking out one side of it at a time, and replacing it with the new lining before taking out the other side; but after a lining has been taken out and replaced in this way, it always settles and cracks, and injures the lining. The stack should be reduced to one-half or less the diameter of the cupola, and should be drawn in by an arch just above the charging-door. A cupola contracted suddenly, as this one is, is better than to have a long tapered contraction, for in this cupola the heat comes up and strikes the arch, and is thrown down on the iron; the sparks strike this arch, and are not so liable to be carried out at the top of the stack as in a long contraction by reducing the diameter of the stack. In this way the heat is more confined and equalized, and will make a more even iron than a cupola with a large stack when the heat escapes freely up the stack."

1859.



The following table shows the dimensions of an ordinary cupola of this type:

| *Dimensions of Ordinary Cupola.* | Feet. | Inches. |
|---|---|---|
| Outside diameter | 4 | 6 |
| Height above hearth | 15 | 0 |
| Inside diameter at tuyeres | 3 | 0 |
| Inside diameter at hearth | 3 | 6 |
| Inside diameter at top (plated with five-sixteenths inch plate 14 feet above the hearth) | 3 | 0 |
| Diameter of main blast-pipe | 0 | 15 |
| " of branch pipes (two) | 0 | $8\frac{3}{4}$ |
| " of tuyere nozzles | 0 | 7 |
| Height of hearth above foundry floor (about) | 3 | 0 |

A cupola of this description has been known to melt from 10 to 20 tons of iron a day, with but 120 lbs. of coke to the ton of metal melted, which consisted of various mixtures of Cleveland hematite and Scotch pig. The diameter was 3 feet 6 inches; height from tapping-hole to charging-floor, 14 feet. It was supplied with blast from a blower, at a pressure of a quarter of a pound to the square inch, and melted at the rate of about $5\frac{1}{2}$ tons an hour.

*The Mackenzie cupola*, Fig. 1860, is largely used in this country. It is generally elliptical in plan, and the blast, instead of being supplied through tuyeres, is admitted through an opening which extends completely round the bottom part of the cupola. The blast is led into a chamber surrounding the boshes of the cupola, and from thence it escapes through the annular opening into the cupola. The cupola is fitted with a drop bottom, which arrangement is almost universally adopted in the United States. 'When first started it is necessary to employ a very light pressure of blast, but as

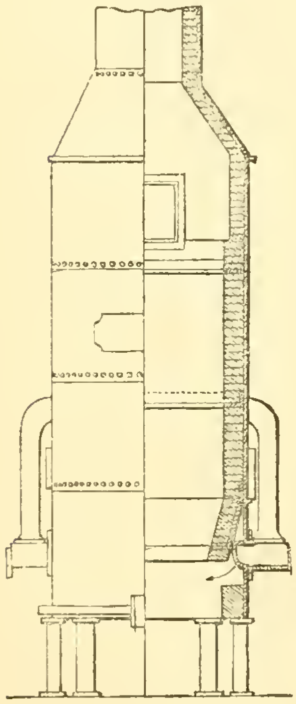
the melting proceeds the pressure is brought up to $2\frac{1}{2}$ lbs. per square inch. The blast is generally applied about 40 minutes after the fire is lit, and the iron begins to run about 20 minutes afterward.

American cupolas as a rule are larger in diameter than those of European design, which is an essential feature when anthracite is used. An arrangement often adopted is to have the sides parallel, but with a convex-shaped belt of the same material as the lining arranged just above the tuyeres, this belt effecting the same object as the boshes in such forms as those of Ireland or Voisin.

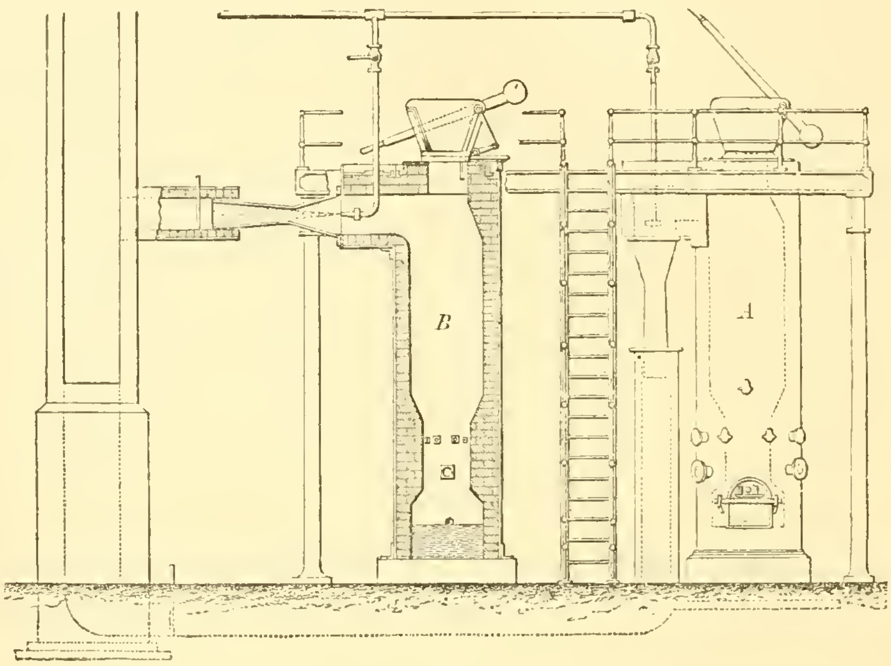
*Ireland's cupola* is built with boshes, and has a cavity of enlarged diameter below them, so as to give increased capacity for the liquid iron. In his first patent there are described two ranges of tuyeres, ordinary ones at the bottom, and smaller but more numerous ones above the boshes, which latter it was proposed to supply with heated blast.

*Woodward's steam-jet cupola* is worked by means of an induced current caused by a steam-jet blowing up the chimney of the cupola, instead of by a blast forced in from below. It is claimed that a considerable saving in fuel is thus effected. Fig. 1861 shows an arrangement of the steam-jet in connection with a cupola provided with a feeding-hopper, with a sliding door to be worked by a lever,

1860.



1861.




so that continuous working is possible. The steam is arranged to blow through a side flue into the chimney. The feeding-hopper to the furnace *A* is represented open, and that of *B* is shut. There are eight air-holes in the upper row and three in the lower row.

*Heaton's cupola* is constructed by building a tall stack on the basis of a cupola, and providing the latter with two rows of large tuyeres; the heat and draught are maintained simply by the ascensive power of the hot air passing up from the cupola and stack or chimney.

*Voisin's cupola* is constructed of double-riveted boiler-plate lined with shaped fire-brick, and the bottom is arranged to drop. The blast is supplied from a belt completely surrounding the cylinder of the boshes, and from this belt two sets of tuyeres, four in each set, deliver the necessary supply of air. The lower set are arranged opposite and at right angles to the main, while the upper set are diagonal to it. The inventor claims that through this arrangement of the tuyeres the gases, being burnt in the interior of the cupola, create a second zone of fusion with those gases alone. In other words, the second set of tuyeres obviate to some extent the evil effect of the formation of carbonic oxide.

A portable cupola with its fan is shown in elevation, Fig. 1862. It is formed of a cylinder *A A*, of sheet-iron one-sixteenth of an inch thick, 2 feet 3 inches in diameter and 4 feet 6 inches high, lined with fire-bricks and clay *B B*, in the usual manner, 4 inches thick. The cupola weighs about 6 cwt., and is easily lifted by the workmen on to a trolly and taken to the place required, when it is lifted off and placed on a temporary staging. The cupola has a belt or air-chamber at *C C*, into which passes the air from the fan, and it has four tuyeres of 2 inches orifice to admit the air to the fire. The yield of metal from so small a cupola is great; as much as $3\frac{1}{2}$ tons have been run down in 7 hours by two men turning the handles of the fan, and nearly $4\frac{1}{2}$ tons by the use of the engine in the same time.

Tuyeres may be classed under two heads, namely, the coiled tuyere and the water-jacketed tuyere.

*The coiled tuyere* is generally made of a coil of wrought-iron tube imbedded in the sides of a hollow case of cast-iron. Sometimes the coils are wound close at the nose of the tuyere, in order more effectually to prevent the cast-iron from burning; and sometimes the tuyere itself is formed entirely of a coil of tube, closely wound from end to end.

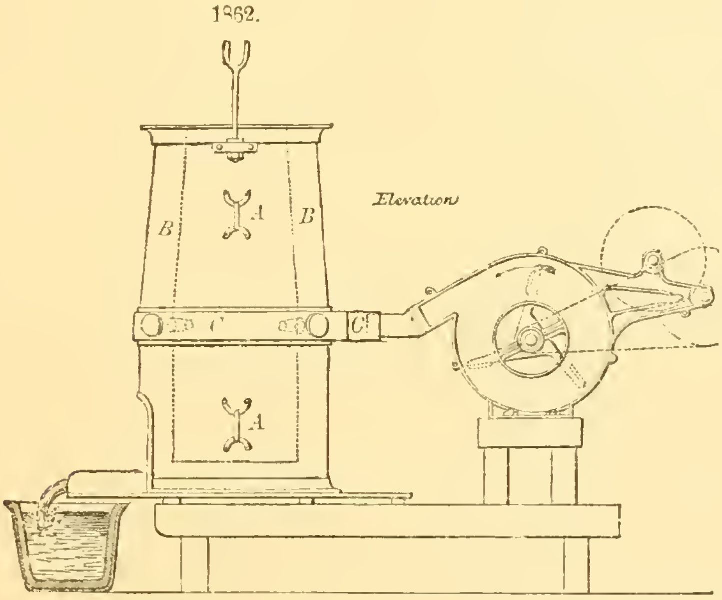
*The water-jacketed tuyere* is generally made of wrought-iron, and consists of two conical tubes of different diameter, connected at each end by rings of wrought-iron welded in, so forming a space between the two concentric walls of the tuyere, which is filled with water supplied under pressure,

and generally brought in through a feed-pipe at or near the bottom of the tuyere, and allowed to escape through a second pipe in the upper side.

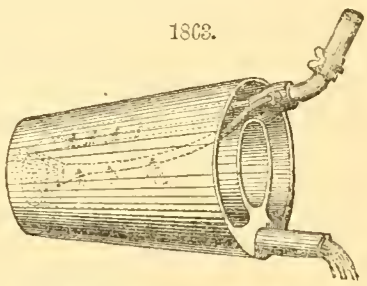
*Phosphor-bronze tuyeres* are generally fixed in a cast-iron casing or box, beyond which they project into the furnace for the greater part of their length; and they are so arranged that they can be turned round in the cast-iron plate or box in order to expose a different side of the tuyere to the action of the materials in the furnace. Greater durability is claimed for phosphor-bronze than for gun-metal or copper; but each metal possesses the same advantage of preventing adherence of slag, scoria, or iron to the nozzle of the tuyere, which is the only object to be gained by the use of copper or its alloys in preference to iron. Additional precautions as to water-supply have to be taken where such metal is used, as, owing to the low temperature at which it melts, a copper tuyere may be more rapidly destroyed than an iron one where any overheating is possible; but under favorable conditions gun-metal, copper, and phosphor-bronze tuyeres have been found very durable, and the advantage gained by keeping the blast-nozzle always clean and fully open is an important one.

*The open-spray tuyere* invented by F. H. Lloyd, Fig. 1863, consists of two concentric conical tubes, closed at the nozzle but open at the rear end. The water-supply is connected in the usual manner with a flexible hose, and various systems of spray-pipes are used to suit various shapes of tuyeres and various conditions of water-supply. The spray-pipes are made either of wrought-iron, brass, or copper, and a sufficient amount of water is allowed to escape through small holes or slits in the spray-pipes to protect every part of the tuyere-casing which is exposed to the heat of the furnace. The spray or jet of water from each hole in the spray-pipe spreads over a considerable surface, and a small number of holes is, if they are properly placed, sufficient to keep the whole interior surface of the tuyere-casing constantly wet. Scarcely any steam is visible, and the waste water passes away,

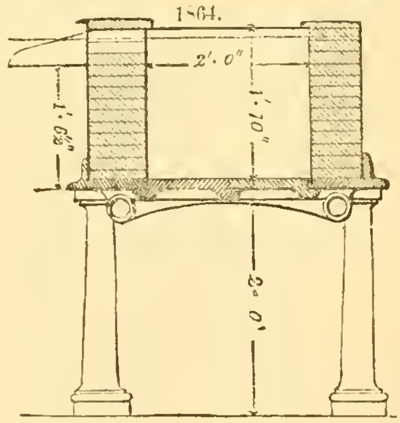
1862.




1863.



1864.




after cooling the tuyere, at a temperature little exceeding that at which it entered, unless a large portion of the tuyere is exposed to violent heat, in which case the temperature of the waste water is certainly no greater than it would be from a tuyere of the old system placed under the same conditions. The spray is principally directed to the loose end of the tuyere, and beats back to some extent on the top and sides, which are also protected by a sufficient number of additional sprays from holes drilled in the spray-pipes. The water falls round the sides and end of the tuyere, and escapes from the back through the waste-water pipe, as shown in Fig. 1863.

The number and position of the tuyere-holes very much depend upon the size of the cupola, the quality of coke, and the nature of the pig to be employed. For some small cupolas, only one tuyere is used, which is placed at the back of the cupola, about 15 inches above the bottom. According as the diameter of the cupola is increased, so must the number of tuyeres be increased around it in the same horizontal plane, so as to generate a uniform heat at all points in the furnace.

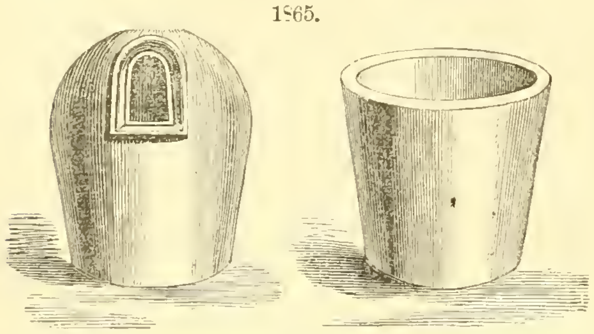
One of the most important modifications of late in the construction of the cupola has been the introduction of the falling hinged trap-door, shown in Voisin's furnace, Fig. 1864, to allow of the whole contents to be dropped into a pit beneath the cupola, after tapping; by this arrangement the cupola is much more easily and quickly emptied when "done work" than by the old and fatiguing process of "raking out." When this arrangement can be adopted, that is, when there is the power to have a clear gangway left beneath the range of cupolas, it is necessary to pay great attention to the proper arrangement and strength of the supports for the cupolas.

For a very excellent discussion on the subject of cupolas and cupola working (from which the foregoing is mainly abridged), the reader is referred to "A Practical Treatise on Casting and Founding," by E. Spretson, London, 1878. A large amount of practical data, etc., will be found in "The Founding of Metals," by Edward Kirk, New York, 1878.

FURNACES, GLASS-MELTING. These usually consist of a heating chamber, in which are disposed the pots or crucibles in which the glass is fused.

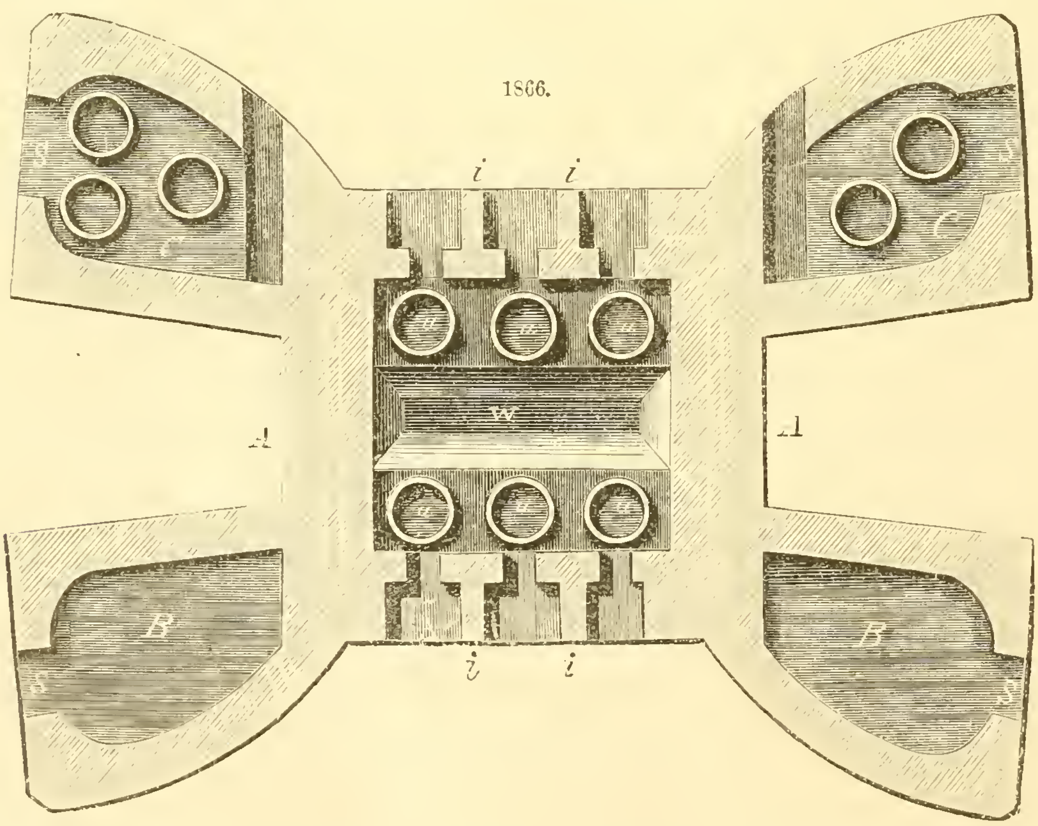
GLASS-POTS OR CRUCIBLES.—The various substances which by their fusion produce glass are melted in large crucibles of refractory earth. These should be capable of supporting for several weeks an exceedingly high temperature, without splitting or vitrification. This temperature, measured by means of the thermo-electric pyrometer, is not less than from 1000° to 1200° C. Bohemian glass is liquid at 1050°, crystal at 925°; and the pasty state at which working is best carried on is at about 770°. The bricks which enter into the construction of the furnaces require the same care in their making as the crucibles. The manufacture of all these appurtenances is in Europe usually carried on in the glass-works, each manufacturer having as a rule particular ideas as to their proper fabrication to suit his requirements. The most refractory clays are employed, as free as possible from iron, lime, magnesia, and the alkalies; and in making the crucibles the greatest care is exercised. In England they are made of the best Stourbridge clay mixed with about one-fifth part of ground potsherds. The work is entirely done by hand. The large pots are about 4 feet in height, 4 feet in diameter at top and somewhat smaller at the bottom, and contain about 25 cwt. of melted glass. Small ones range from 19½ to 39 inches in height, and from 2 to 2.7 inches in thickness, after being baked. The average duration of a pot in the furnace is about 8 weeks. In the case of window and ordinary bottle glass, the pot is a plain round vessel, open at the top, as shown at the right of Fig. 1865; but in melting flint-glass, it being necessary to protect the metal from all external impurities, the top of the pot is made in the form of an arch or hood, with a small opening on one side near the top, which corresponds to the nose-hole of the furnace, and from which the workman withdraws the melted glass.

1865.



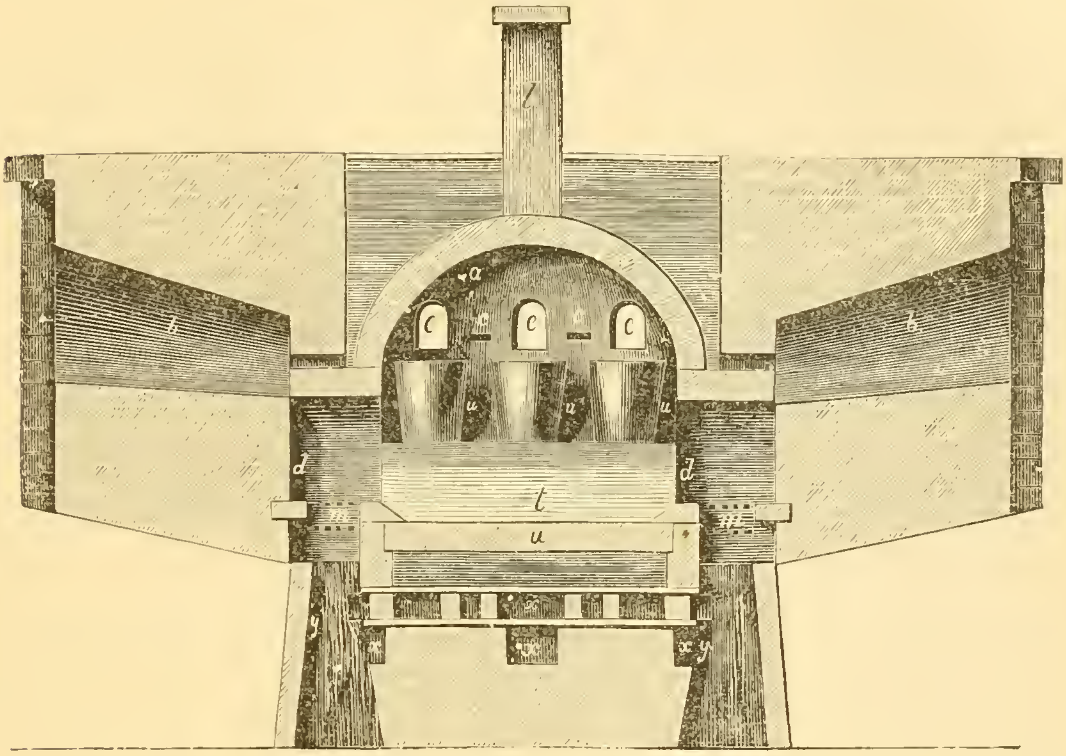
Peligot gives the following composition of crucibles and pots: *Crucibles*—Fatty clay of Forges, 100 parts; cement, 100 parts; pulverized potsherds, 10 parts. *Pots*—Fatty clay of Ardennes, 350 kilogrammes; same, calcined, 260 kilogrammes; potsherds, 100 kilogrammes. These ingredients, moistened with water, are made into a homogeneous paste in a mechanical mixer, and are afterward kneaded in manner similar to pottery clay. About 300 kilogrammes are required to make a pot. The material is formed into lumps and allowed to season for several weeks in a moist place, by which process it acquires the necessary plasticity. The manner of making the pots in France consists in building them up of small cylinders of the prepared clay called *pastons* or *columbins*. Generally a wooden vessel is used as a mould, and this is lined inside with wet cloth. The columbins, previously prepared and flattened on one side, are placed against the cloth, beginning at the centre

1866.

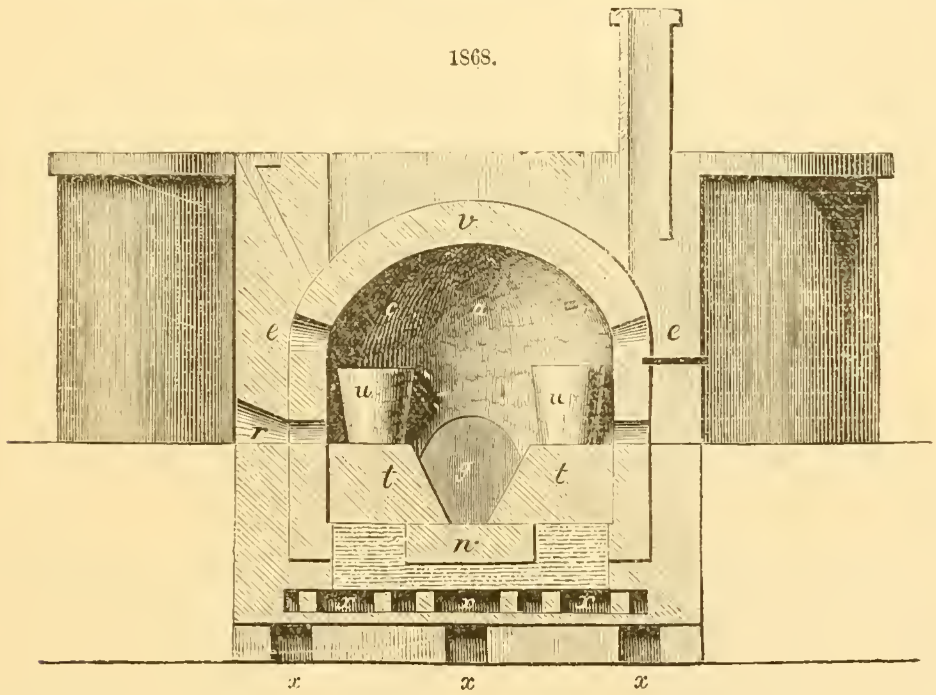



of the bottom. They are thus built up, range after range; and as they are put in place they are rubbed together so as to make them unite. When the top of the moulding vessel is reached, the whole is removed to a warm apartment, and the interior of the pot is pounded smooth with marble mallets. It is then left in the mould for several days, after which it is turned out, and any defects

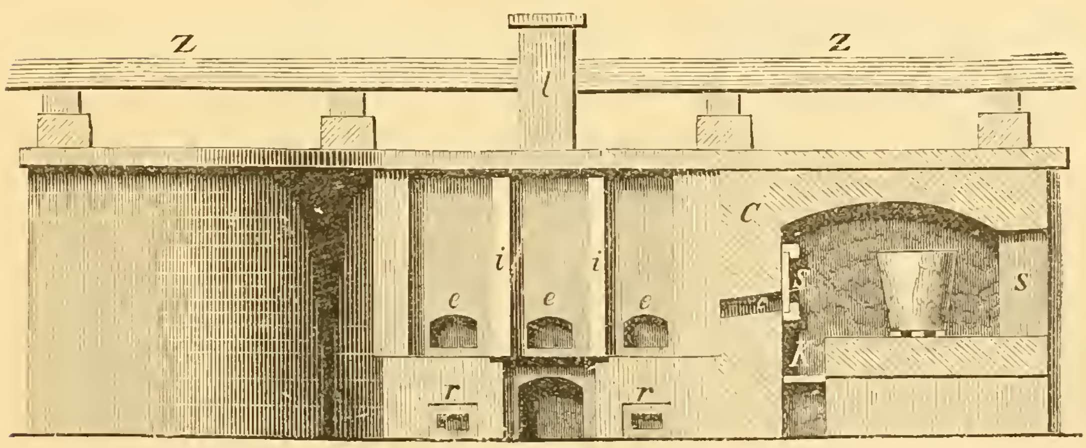
1867.




1868.




1869.



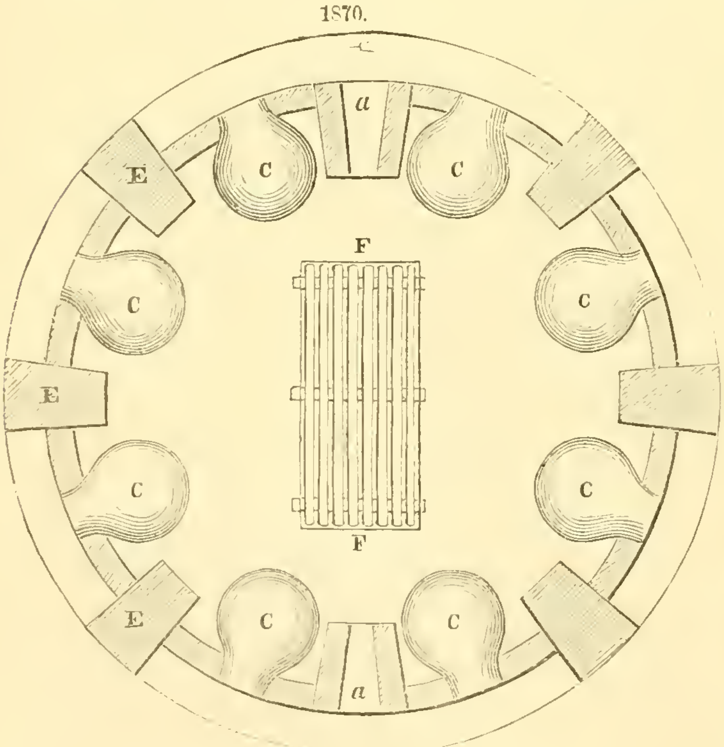
on the exterior surface are repaired. The pot is afterward left to dry in a chamber heated to from 30° to 40° C. for from 4 to 8 months. Then it is gradually baked at a red heat.

Furnace Bricks.—A glass-furnace after being once fired is always kept in heat until its stoppage is necessary on account of deterioration. Then it is generally built anew. The bricks, having therefore to withstand a very high temperature for so long a time, are chosen with great care, especially those used in forming the vaults and arches. Refractory clay alone does not produce sufficiently resisting bricks, and hence very pure white sand is added to it. This material is best obtained from quartziferous rock or pebbles, ground and treated with sulphuric acid to remove all traces of iron. Vault-bricks should contain from 80 to 85 per cent. of this sand. Those which come in contact with the glass which flows over during melting or on the breakage of the pots may contain very much less. If they are too silicious, they are rapidly scored by the glass which almost constantly falls from the pot into the furnace. If, on the other hand, they are made of nearly pure clay, they resist much better the dissolving action of the basic elements of the glass. The following is a good mixture for vault-bricks: 250 kilogrammes of clay, 250 kilogrammes of calcined clay from old furnace-vaults, and 100 kilogrammes of purified quartz sand. In Wales a very excellent brick is made from agglomerated quartz, the material being obtained at Dinas in the Neath valley. It is nearly pure silex. The rock, reduced to powder, is mixed with about one per cent. of lime and a quantity of water sufficient to agglutinate the mass, when it is compressed in iron moulds. It is thus made into bricks, dried, and then baked at a high temperature. The lime acts as a kind of flux at the surface of the quartz grains and determines their agglomeration. These bricks expand by heat, while those of clay contract.

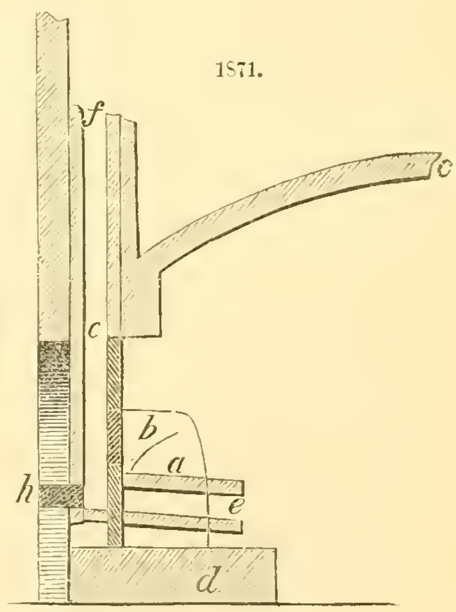
Furnaces.—The furnaces used in glass-making may be divided into four classes: 1, ordinary furnaces; 2, Siemens furnaces; 3, Boetius furnaces; and 4, single-pot furnaces.

*Ordinary Furnaces.*—These are heated either with coal or wood. They are usually of circular, oval, or rectangular form, and contain from 6 to 12 pots. Access is afforded to each pot by a separate opening, which is closed during the melting. Figs. 1866 to 1869 represent a four-sided furnace intended for 6 pots. Fig. 1866 is a horizontal section, Fig. 1867 a perpendicular section through the teazing arch, Fig. 1868 a perpendicular section through the edges or seats, and Fig. 1869 a front view with a section of the fritting kiln. There are four side kilns connected with the main furnace *A A*, Fig. 1866, in the shape of four wings, viz.: two cooling or annealing furnaces *B B*, and two fritting kilns *C C*. Above the foundation, in which the drains *x x x* are excavated, the sole-stone *w* is placed, which forms the bottom of the fire-room. The two fireplaces and grates *m m*, Fig. 1867, are situated above the ash-pits *y*, and are exactly opposite to each other; they are supplied with fuel from the arches *b b* and *d d*, while the flames from the two extremities meet in the fire-room *g*, Fig. 1868, and enter together the space *a a* occupied by the pots *u u u u*, and, reverberating from the four-sided arch, escape at last through the flues *c c*, 8 inches in width, into the side ovens, of which two can be heated by separate fires *K*, Fig. 1869; the damper in the flues *c* shuts off the flame from the furnace *A A* when required. The uprights *i i i i* separate the working spaces of the glass-blowers, who obtain access to the glass in the pots through the working-

1870.




1871.

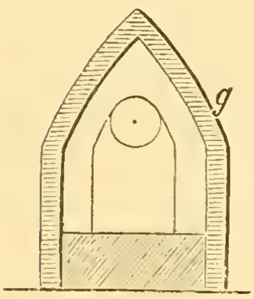



holes *c c c*. Immediately below these are the openings *r r r*, which can be opened for removing the pots when broken or worn out from the sieges, to which they often adhere. In order to retain the heat in the furnace, the working-holes are made as narrow as possible, and consequently much smaller than the pots; when it is necessary to change the latter, they are removed through the side arches, of which there are two in every furnace, kept constantly bricked up except when actually in

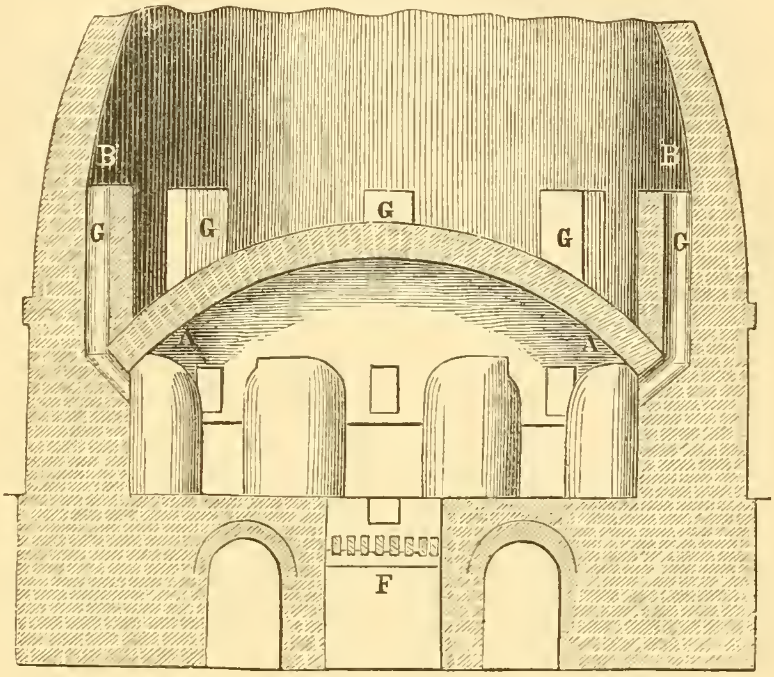
use. Chimneys (*l*, Fig. 1869) are sometimes erected over one or more of the working-holes to carry off the heat and the vapors from the pots; these, however, are not essential, and are not often used. The side-kilns are accessible by the doors *S S S*. Wood is placed on the scaffolding *Z* to dry. The cupola or arch *v* is walled over with ordinary bricks, and the corners are filled with sand and earth.

The round melting-furnaces, although very commonly used, are not so commodious as those of quadrangular form under the same circumstances. Figs. 1870 to 1873 represent a furnace of this

1872.

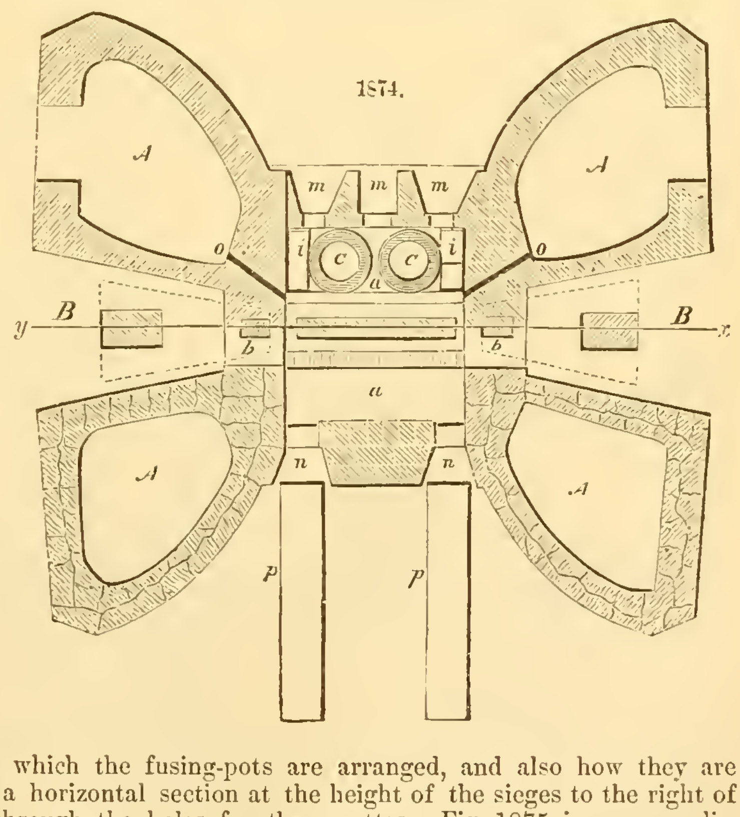



1873.




kind designed for making flint-glass. Fig. 1870 is a ground plan of the melting-furnace. The pots *C* are situated at equal distances between the pillars or piers *E*, which support the exterior dome. At *a a* are openings in two of the piers for charging with fuel. Fig. 1871 shows how the heat is carried round the pot in its exit from the furnace. The pots are covered with hood-shaped tops, and these fit the working-holes of the furnace, so that the smoke and heat cannot escape in the same way as in the usual glass furnaces. *a* is the pot, with the top *b*; *c* is the roof of the furnace; *d*, the "siege" on which the pots are placed; and *e e*, a flue, low down, which passes between the furnace and the cone till it reaches a point *f*, where it enters the cone itself. *g*, Fig. 1872, is a front view of the pot and arch of the cone, which allows the workmen to approach the opening in the furnace, against which the mouth of the pot is placed. *h* is an opening direct from the outside into the flue, for the purpose of keeping it clean. Fig. 1873 is a general view of the melting-furnace, cone, and working-holes. It consists of two domes, *A A*, *B B*, one within the other, of which the interior one is flat, and the exterior of considerable altitude, terminating in a high chimney. The only connection between the domes is by the flues *G G*, which are situated one on each side of the crucibles, so that they receive the whole body of the flame as it passes from the fireplace to the exterior dome, and thence to the chimney.

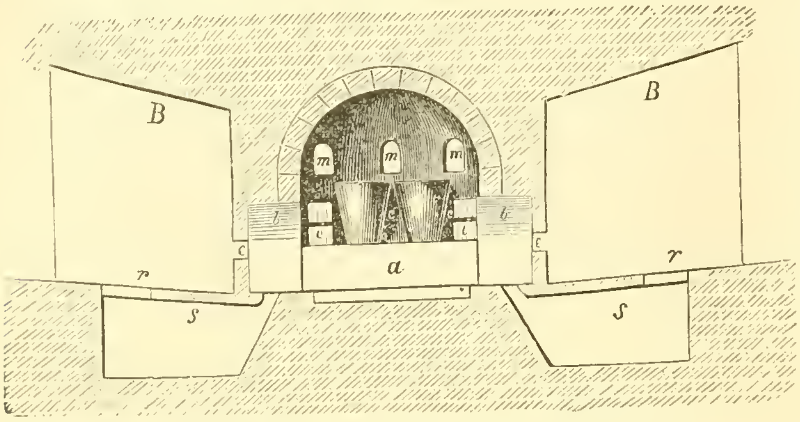
1874.




The following drawings of a plate-glass furnace exhibit the manner in which the fusing-pots are arranged, and also how they are inserted and removed. Fig. 1874 is a horizontal section at the height of the sieges to the right of *x y*, and somewhat lower to the left, through the holes for the cuvettes. Fig. 1875 is a perpendicular section through the line *x y*. The melting-furnace is surrounded by four side furnaces *A A A A*, used for burning and heating the pots, and so arranged that the whole length of the sides with the siege *a* is left open and free of access. Thus the two remaining sides are only accessible by the

narrow passages *B B*, and these are connected with the large apertures *b b*. These apertures are used for the insertion of the pots *C C*, and at the same time for stoking the fire: for the latter purpose they would be too large, and allow too much heat to be lost; they are consequently bricked up above and closed in front by slabs of clay, with the exception of the small apertures *c e*. A grate is indispensable when coal is used, but not when wood is the ordinary fuel. The flame travels from the melting-furnace, after passing between the sieges and heating the pots *C C* and the cuvettes *i i*, through the flues *o o* into the side furnaces *A*. Two rows of holes are left in the free sides of the furnace. By means of the upper working-holes *m m m*, the melting-pots are accessible for the purposes of ladling; through the two lower holes *n n* the cuvettes are inserted or removed upon the iron slabs *p p*, which must consequently be exactly upon the same level as the sieges. All the holes can be closed by movable plates at pleasure. The draught can be regulated through *r r*, and the ash collects in *s s*.

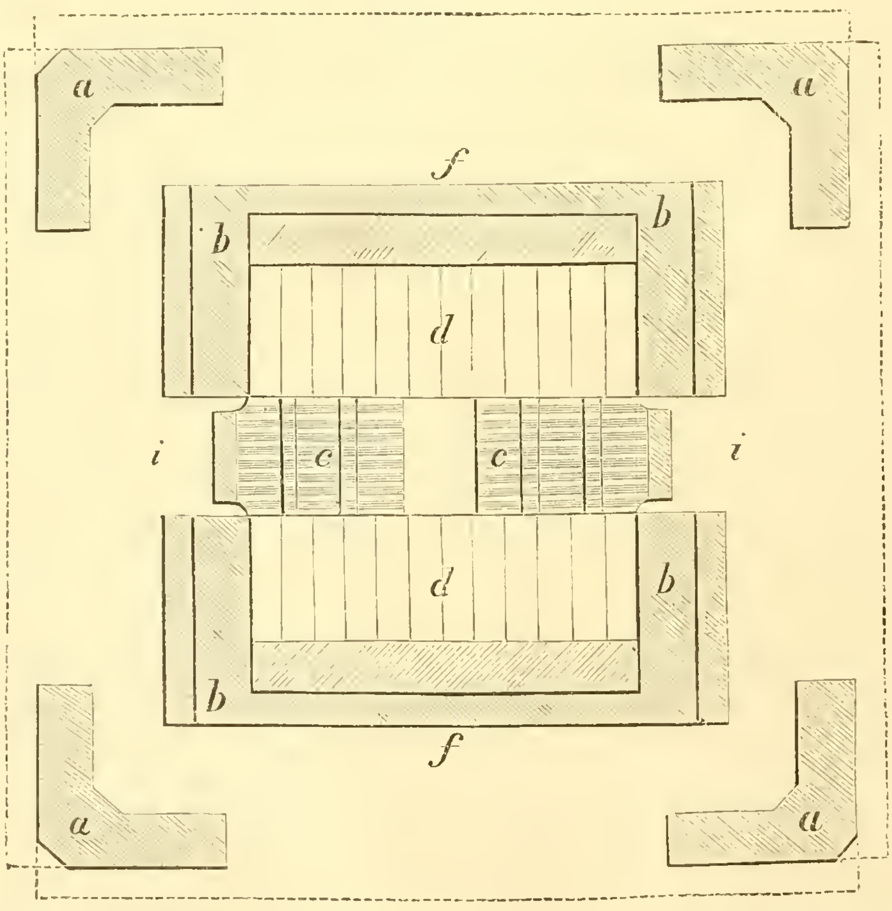
1875.




Figs. 1876 to 1878 show a ground plan of a melting-furnace for crown glass, and the elevation of an end and side. *a a a a* are the stone pillars which carry the cone; *b b b b*, the walls of the furnace; *c c*, the grate-bars upon which the fuel lies; *d d*, the "sieges," or position which the melting-pots occupy, one opposite each opening *c c c*. *g* is an elevation of the sides *f f*, and *h* an elevation of the ends *i i* of the furnace. *k k k* are temporary openings to enable the workmen to insert large iron levers to assist in placing the pots, which are carried on a machine, in a red-hot state, into the furnace through the other temporary opening *l*.

*The Siemens Gas Furnaces* involve two principles: 1. For the direct action of the combustible that of the products resulting from its distillation is substituted. 2. These products, consisting of carbonic oxide, carburetted hydrogen, and hydrogen, are directed in company with air, but without being mingled with the latter, into two chambers filled with fire-brick previously heated to a red heat

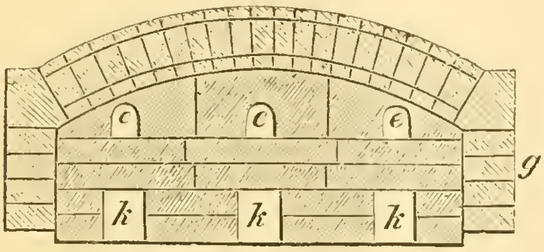
1876.



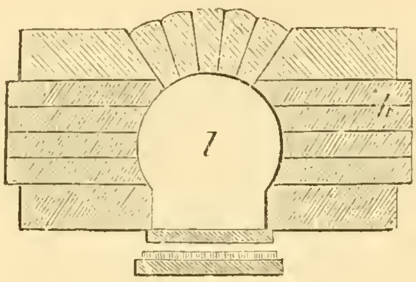

by the furnace flame. The gases and air are consequently heated by their contact with the bricks. These chambers are termed "regenerators," and the gases, after traversing them, are led into the furnace, adding to the heat which they have already acquired that which is due to chemical action. The flame which is the consequence of the latter starts at a short distance from the bench on which

the crucibles rest, traverses the furnace, determines the effects due to its high temperature, and on leaving penetrates into two other regenerators, there giving up nearly all its remaining heat, the gases of combustion escaping from the chimney considerably cooled. Thus the two inlet regenerators

1877.

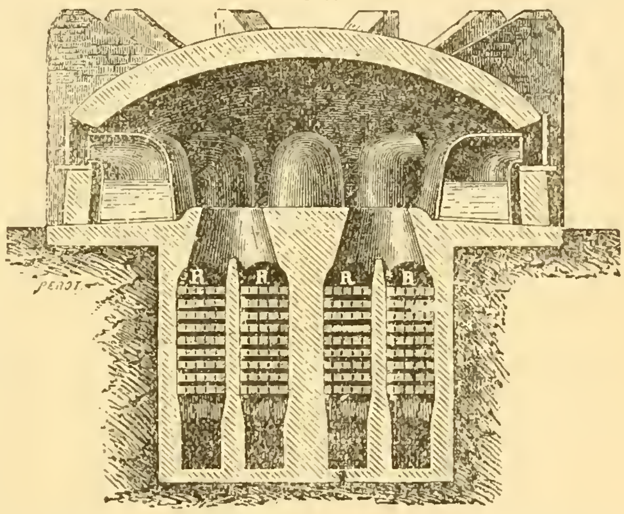



1878.



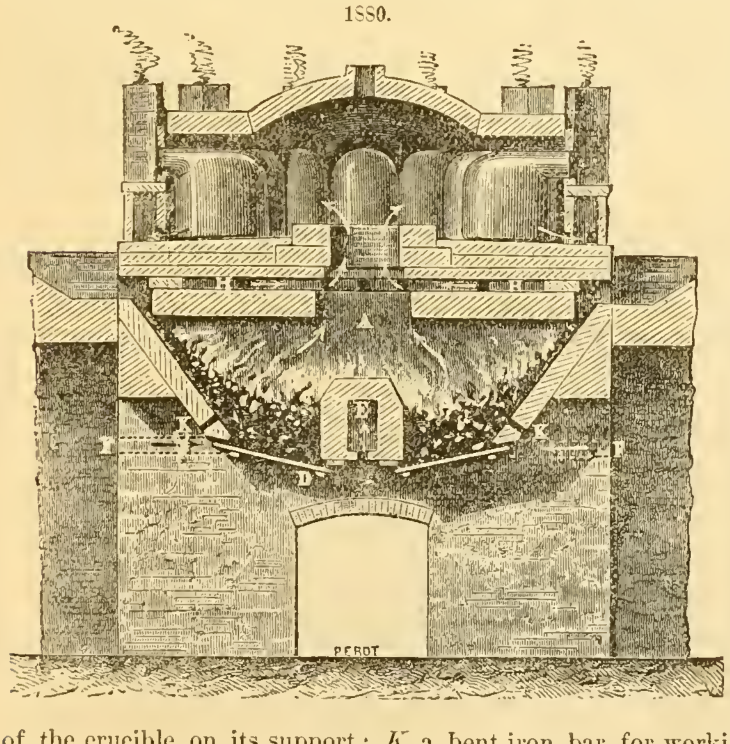

and the two outlet regenerators act inversely. The first pair are traversed from bottom to top, one by the gaseous products, the other by the air. The second pair are traversed from top to bottom by the mixture of gases leaving the furnace; consequently the latter gases raise the temperature of the brick lining. By means of valves, moved every half hour, the four chambers are used alternately; that is, those previously heated by the escaping gases are employed to heat the entering gases and air, and the former entry regenerators now become those of outlet. This arrangement will be understood from Fig. 1879, which is a vertical section of furnace and regenerators. The gases and air enter through the two contiguous chambers on the right, and mingle and burn a little above them; then escaping, they pass into the chambers on the left, which they elevate to a high temperature.

1879.



*The Boetius Furnace*, Fig. 1880, is simpler and less costly than that just described. The fuel charged by the two lateral openings furnishes carburets of hydrogen and other combustible products, and falls on the grates *D* in the form of coke. This burns, yielding carbonic acid, which on traversing the layer of incandescent coal becomes partially converted into carbonic oxide. The grate allows of the passage of air only just sufficient to consume the coke. In order to burn the gases formed, air is drawn in at *E* and *F*, and is caused to circulate in its conduits *H* around the fire, thus becoming heated. It then mixes with the gases, and the flame produced passes up through the furnace and escapes by the chimneys shown. An economy of 30 per cent. in fuel is claimed for this furnace over others. It admits of a higher temperature being obtained, and of the use of inferior grades of fuel.

1880.

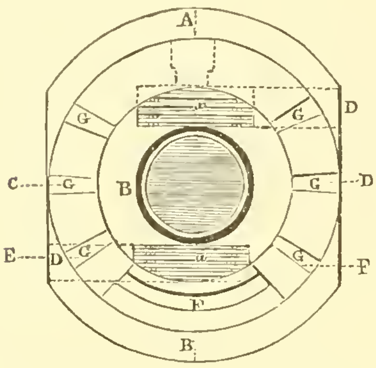


*Single-Pot Furnace.*—An example of this construction is shown in Figs. 1881 to 1884. Fig. 1881 is a horizontal projection of the furnace and crucible. Fig. 1882, section along the line *E F*, Fig. 1881; that is to say, along the flue. Fig. 1883, vertical section along the line *C D* of the plan. Fig. 1884, vertical section along the line *A B* of the plan. *A* is the foundation or support for the covered crucible *B*; *C C* are the walls of the furnace; *D D*, openings through which the coal is thrown on the grate; *E*, arch or crown of the furnace; *F*, door or opening through which the crucible *B* is introduced and taken out; *G*, six chimneys; *H*, an opening; *I*, hole to facilitate the placing of the crucible on its support; *K*, a bent iron bar for working the fire-clay cylinder; *L*, a support with a roller across, on which the bar *K* is supported; *M*, a hole with a stopper through which the coal is thrown; *N*, aperture with stopper, through which the grate is cleared; *O*, hood of sheet-iron,

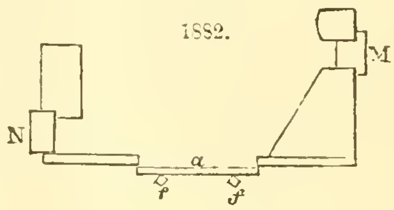
under which the chimneys terminate; *a a*, grate of furnace; *b*, throat of crucible; *c*, level of the melted glass; *d*, fire-clay cylinder for stirring; *e*, opening; *f*, grate-bars; and *g*, door of opening *e*.

Mr. Siemens has devised a furnace in which the sole is divided into three compartments by trans-

1881.

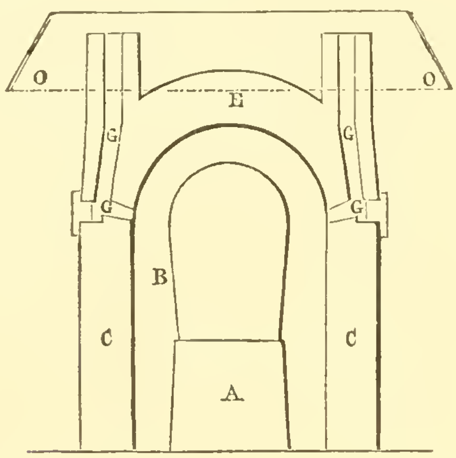


1882.

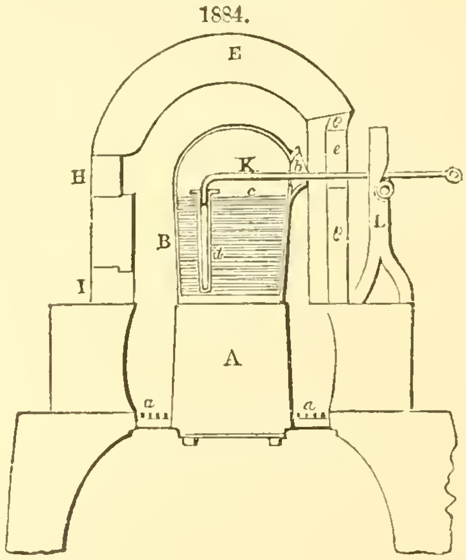


verse partitions. The first serves for fusion, the second for fining, and the third for the collecting of the glass. In another furnace, in operation in Dresden, the second partition is suppressed and 80 annuli of clay are substituted, in which the glass circulates during the fining. MM. Videau and Clémandot have constructed a furnace in which a huge melting-vat is substituted for the pots.

1883.

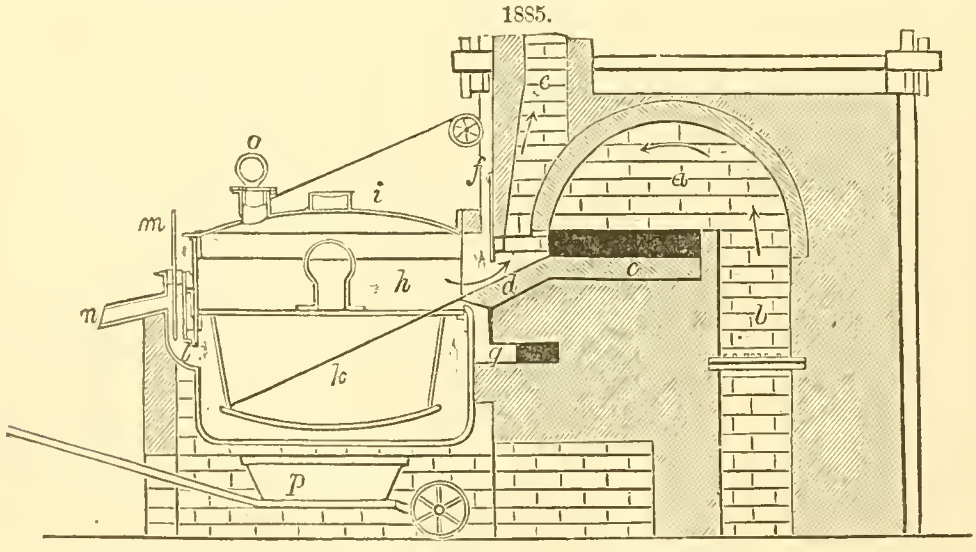


1884.



Figs. 1885 and 1886 represent M. de la Bastie's furnace for the manufacture of tempered glass. Fig. 1885 is a section of the oven and bath, suitable for tempering shaped articles. *a* is an oven heated by a furnace *b*, having its floor *c* made in one piece of a refractory material with a polished surface; from this a slope *d*, of the same material, leads into the bath *h*, which is provided with a

1885.

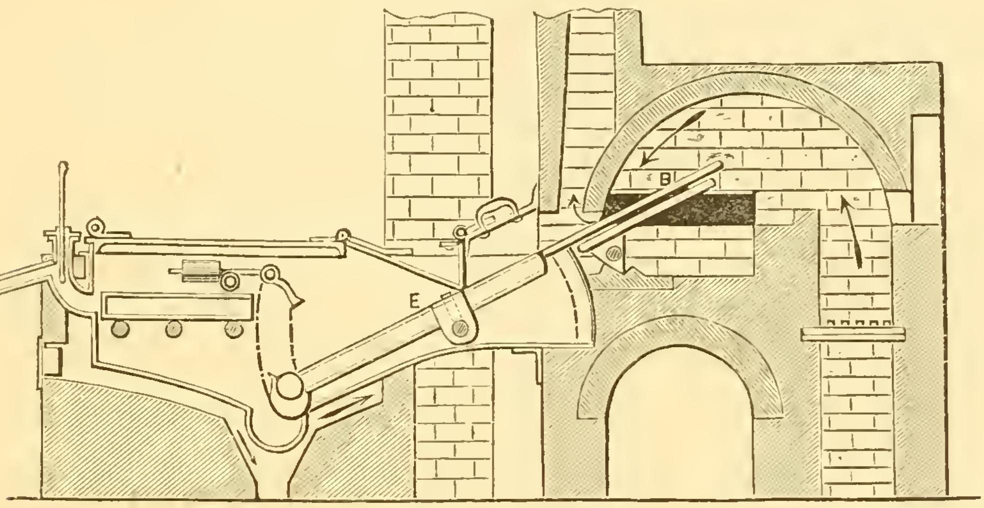


lid *i* for the purpose of excluding the air, and a basket *k* of fine wire gauze to receive the heated articles. At the back of the oven *a* is a chamber into which the articles are first introduced, and where they are partially heated; they are then pushed through an aperture in the dividing-wall into the oven *a*, where the final heating takes place. When the temperature is sufficiently high, the ash-

pit and fire-doors are closed, and rendered air-tight by luting, the fire being maintained by pieces of fuel introduced through a small aperture in the furnace-door, after which the draught is stopped by closing the damper. The vertical damper *f* is then raised, which operation both causes the flame to pass by the flue *g* to a second chimney, passing along the slope *d* and heating it, and also opens the communication between the oven and the bath, which is filled with the prepared liquid. A fire-truck *p*, charged with live fuel, heats the bath to the desired temperature. *l* is a tube, in which is a thermometer *m*, for ascertaining the temperature of the bath: by this tube also the contents of the bath may be added to; *n* is an overflow-pipe. The plug *o* on the cover may be removed to observe the interior without wholly uncovering the bath. The workman watches the glass through an eye-hole, and, when the article has arrived at the proper heat, he pushes it by an iron rod to the slope *d*, whence it slides down into the bath, and is received into the basket *k*. When the glass has cooled to the temperature of the liquid, the lid is removed, and the basket is taken out with the tempered glass. The function of the lid is to stop the supply of air, and thus prevent the combustion of the oleaginous liquid, which might otherwise take place on the introduction of articles raised to a red heat; the wire basket facilitates the withdrawal of the tempered articles from the bath, and, offering a yielding surface to the softened glass, the latter incurs no risk of alteration in form. A layer of sand may be substituted for the basket of wire gauze.

Fig. 1886 represents the same furnace adapted for the annealing of flat plates. Its general construction is the same as above given, the special feature being the rocking-table *E* and the movable

1886.




furnace-bed *B*. When the plate which rests on this furnace-bed is sufficiently heated, the bed is tipped up till it is on a level with the rocking-table, when the plate slides down into the bath, which has a curve at the bottom to contain any pieces which may be accidentally broken off. When the plate has been a proper time in the bath, *E* is tilted up, and, by means of an ingenious adaptation of levers, the plate is removed and slid out, when the rocking-plate is returned and remains in a position to receive the next plate.

For works for reference on glass-making, see GLASS, MANUFACTURE OF.

FURNACES, METALLURGICAL, *other than for iron and steel.* The furnaces chiefly used in the United States for the roasting of ores of silver, copper, etc., are the Stetefeldt and the Bruckner revolving-cylinder furnaces.

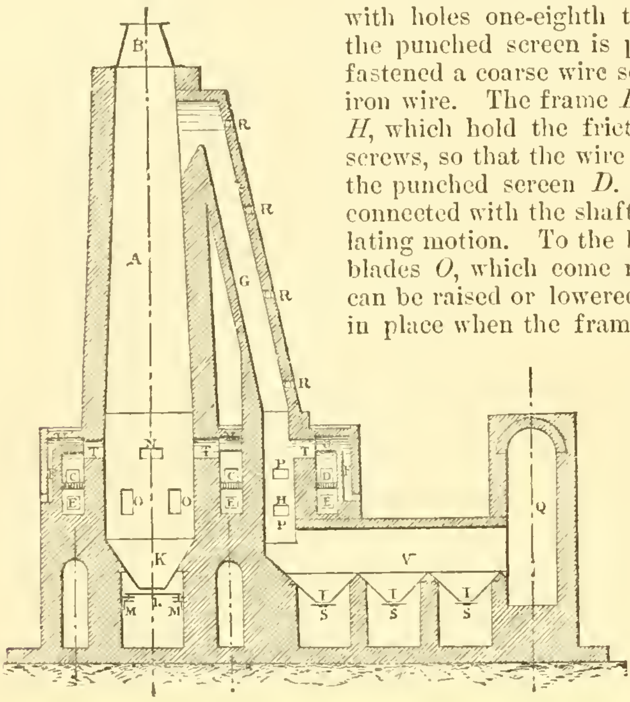
*The Stetefeldt Furnace*, represented in Fig. 1887, is largely employed in the treatment of silver ore. The percentage of silver chloridized varies according to the character of ore and the care with which the furnace is managed. Results as high as 97 per cent., the manufacturers state, have been obtained, while the average chloridations are claimed to range between 87 and 93 per cent. The furnace can be used for oxidizing as well as for chloridizing roasting, but it is mainly for chloridizing of silver ores that it has been generally introduced. It may also be used for the oxidizing roasting of gold-bearing sulphurets, preparatory to extracting gold by Plattner's process or by amalgamation; for oxidizing or chloridizing roasting of sulphuret copper ores, to prepare them for one of the leaching processes; and for the oxidizing roasting and slagging of galena ores—through suitable changes in its construction—preparatory to their reduction in the blast furnace.

*A* is the shaft into which the pulverized ore is showered by the feeding machine, placed on the top of the cast-iron frame *B*. The shaft is heated by two fireplaces, *C*. The ash-pits of these are closed by iron doors, having an opening *E*, provided with a slide, so that more or less air can be admitted below the grate, and consequently more or less heat generated. In order to obtain a perfect combustion of the gases leaving the fire-box through the slit *T*, an air-slit *U*, connected with the air-channel *F*, is arranged above the arch of the fire-box. This slit also supplies the air necessary for the oxidation of the sulphur and the base metals. Another advantage of this construction is, that the arches above the fire-box and fire-bridge are cooled and prevented from burning out. The roasted ore accumulates in the hopper *K*, and is discharged into an iron car by pulling the damper *L*, which rests on brackets with friction-rollers *M*. *N* is an observation door, and also serves for cleaning the fire-bridges. *O O* are doors to admit tools in case the roasted ore is sticky and adheres to the walls. The gases and fine ore-dust, which form a considerable portion of the charge, leave the shaft through the flue *G*. The doors *R* are provided to clean this flue, which is necessary with some

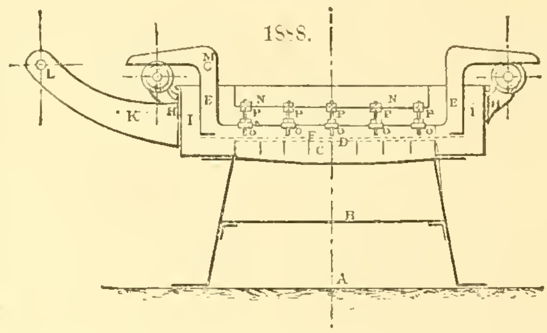
ores about once a month. $D$ is an auxiliary fireplace, constructed in the same manner as the fireplaces on the shaft, which is provided to roast the ore-dust escaping through the flue $G$, in passing through the chamber $H$. $P P$ are doors for observation and cleaning. The larger portion of the roasted dust settles in the chamber $V$, provided with discharge-hoppers $I$, from which the charge is drawn into iron cars by moving the dampers $S$. The rest of the dust is collected in a system of dust-chambers $Q$, connected with a chimney which should rise from 40 to 50 feet above the top of the shaft. At the end of the dust-chambers is a damper by which the draught of the furnace can be regulated. The dry kiln can also be used as a dust-chamber, and the waste heat of the furnace utilized for drying the ore before crushing it. The firing of the furnace is done on one side, and all discharges are located on the opposite side.

The feeding machine is shown in Fig. 1888. The cast-iron frame $A$, which is placed on top of the shaft, is provided with a damper $B$, which is drawn out when the furnace is in operation, but inserted when the feeding machine stops for any length of time, or if screens have to be replaced. $C$ is a cast-iron grate, to the top of which is fastened the punched screen $D$. The latter is made of Russian sheet-iron, or of cast-steel plate, with holes one-eighth to one-tenth of an inch in diameter. Above the punched screen is placed a frame $E$, to the bottom of which is fastened a coarse wire screen $F$, generally No. 3, made of extra-heavy iron wire. The frame $E$ rests upon friction-rollers $G$. The brackets $H$, which hold the friction-rollers, can be raised or lowered by set-screws, so that the wire screen $F$ can be brought more or less close to the punched screen $D$. The brackets $K$ carry an eccentric shaft $L$, connected with the shaft $M$, from which the frame $E$ receives an oscillating motion. To the brackets $N$ are fastened transverse stationary blades $O$, which come nearly in contact with the wire screen $F$, and can be raised or lowered by the nuts $P$. These blades keep the pulp in place when the frame $E$ is in motion, and also act as distributors

1887.



1888.



of the pulp over the whole surface of the screen. The hopper $I$ receives the ore from an elevator, which draws its supply from a hopper into which the pulverized ore is discharged from the crushing machinery. The ore is generally pulverized through a No. 40 screen. By means of a set of cone-pulleys the speed of the flame $E$ can be changed from 20 to 60 strokes per minute, whereby the amount of ore fed into the furnace is regulated. This can also be done to some extent by changing the distances between the punched screen $D$, the wire screen $F$, and the blades $O$.

The manufacturers give the following example as showing the cost of roasting in a Stetefeldt furnace of 25 tons capacity, in 24 hours, at stated prices for labor, fuel, and salt, such as are generally paid in mining districts of Nevada:

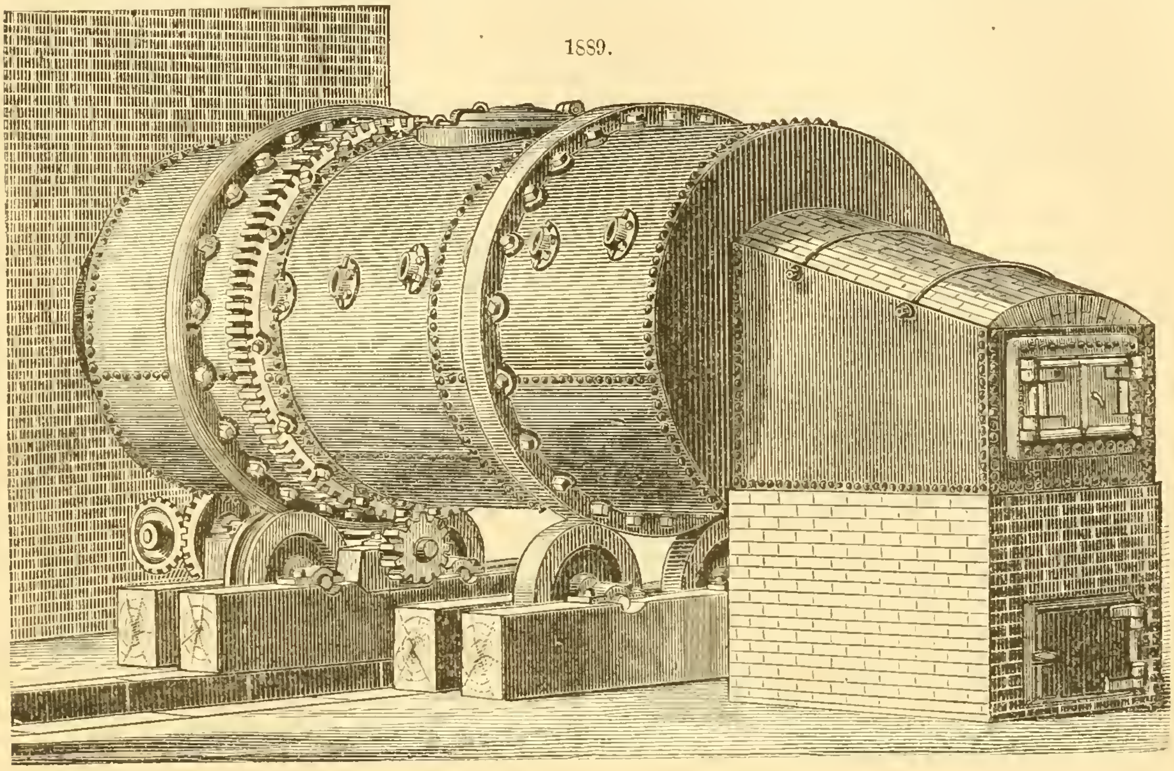
| | |
|---|---|
| 2 firemen, at $4.50 | $ 9 00 |
| 4 pulp-coolers, at $4 | 16 00 |
| 2¾ cords of wood, at $8 | 22 00 |
| Wear and tear of screens, etc | 1 00 |
| Labor and fuel for 25 tons | $48 00 |
| Labor and fuel, per ton | $1 92 |
| 7 per cent. salt, at $40 per ton | 2 80 |
| Expense of chloridizing roasting, per ton | $4 72 |

*The Bruckner Revolving Furnace*, Figs. 1889 and 1890, is also largely employed for the purpose of roasting and chloridizing silver ores. The exterior of the cylinder is a sheet of boiler iron, 12 feet long by 5 feet 6 inches in diameter. The ends are partially closed with similar material, leaving in the centre a circular opening about 2 feet in diameter, bounded by a flange projecting several inches. Upon one side is placed an opening closed by a hinged door. Upon the outside of the cylinder are bolted three bands, in which the section of the first is square, and that of the third semicircular; the second or middle band is a strong spur-gear. Passing through the cylinder are six pipes parallel to one another, in a plane at an angle of 15° to the axis of the cylinder; these pipes also lie in this plane at an angle of 30° to 35° to the longitudinal axis of the plane, as shown in Fig. 1890, where the internal arrangement of the cylinder is seen, a perforated diaphragm being formed through part of the cylinder by means of perforated plates placed between the above-described pipes, the plates being held in place by longitudinal grooves upon these pipes. The cylinder is supported upon four

large friction-rollers, two of which are grooved upon their periphery to loosely fit the semicircular band, thus holding the cylinder longitudinally in place. The other two friction-rollers are made without a groove, and bear upon the square band, thus accommodating themselves to the expansion and contraction of the cylinder, or any irregularities of form. Rotary motion is given to the cylinder by means of a pinion placed under the cylinder and gearing into the spur-gear band.

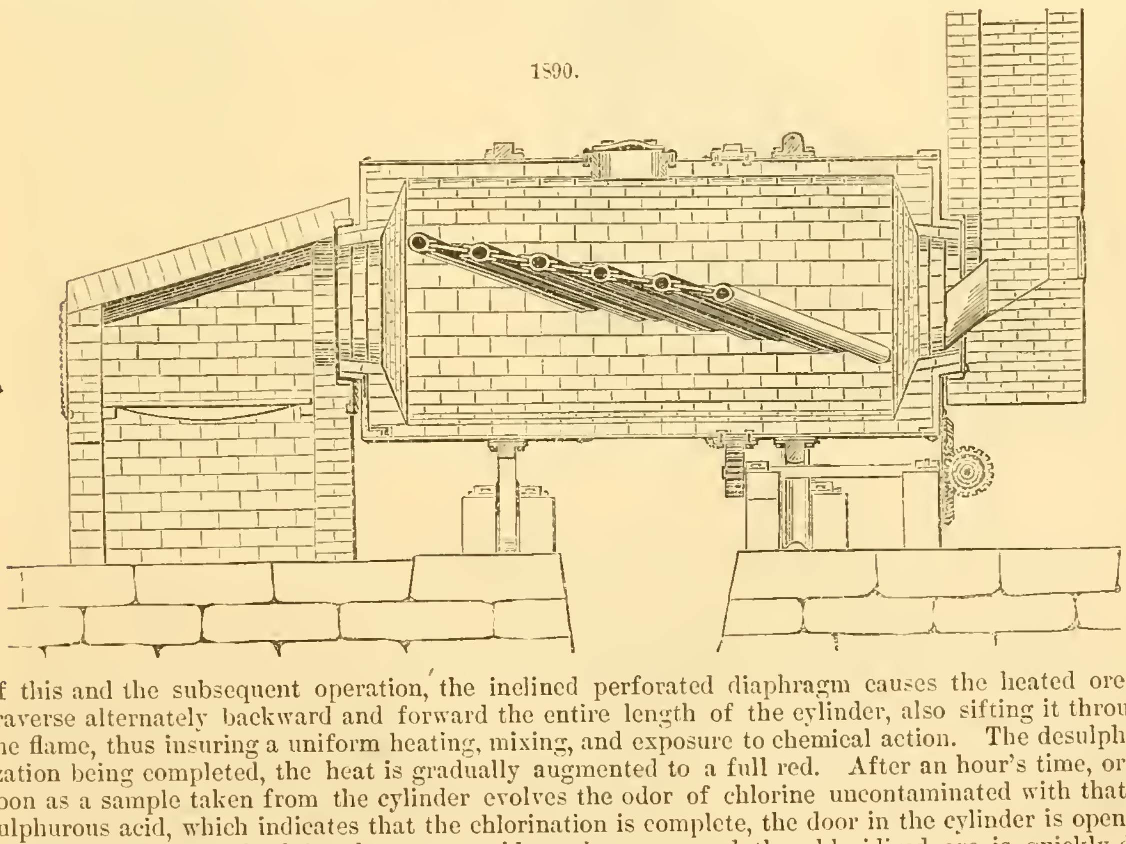
A fire having been kindled in the fire-box, the cylinder is allowed to revolve slowly until heated to

1889.



a dull red, and is then brought to rest with the door on top. In this position about 4,000 lbs. of pulverized ore and 200 to 400 lbs. of salt are introduced; the door is closed and securely fastened, and the cylinder is made to revolve at the slower speed of from one-half to one turn per minute. The fire is so regulated that after an hour's time the sulphur contained in the ore begins to burn, the ore in the cylinder being retained at a dull red for some time. (In those ores containing a large amount of sulphur, little or no additional fuel is required for desulphurization.) During the whole

1890.

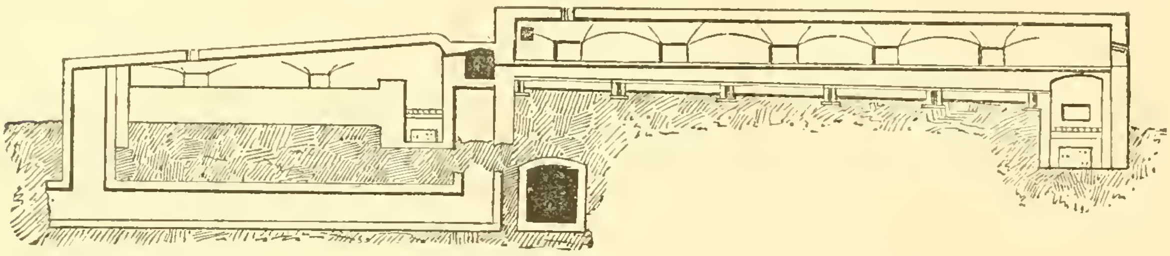


of this and the subsequent operation, the inclined perforated diaphragm causes the heated ore to traverse alternately backward and forward the entire length of the cylinder, also sifting it through the flame, thus insuring a uniform heating, mixing, and exposure to chemical action. The desulphurization being completed, the heat is gradually augmented to a full red. After an hour's time, or as soon as a sample taken from the cylinder evolves the odor of chlorine uncontaminated with that of sulphurous acid, which indicates that the chlorination is complete, the door in the cylinder is opened, and the cylinder revolved by the more rapid moving gear, and the chloridized ore is quickly dis-

charged, being received into a car, shoot, or other conveyer, according to the construction of the mill. The total weight of the iron parts is 16,000 lbs. The placing of the foundation and the erection of brickwork, for fire-box, cylinder-linings, and dust-chambers, will vary greatly according to local circumstances. The capacity of a cylinder in 24 hours is, as reported by Mr. Charles E. Sherman and endorsed by B. O. Cutter, from 8 to 10 tons (in very refractory ores the daily average would be less), the chloridizing being up to 96 per cent. These statements are based upon their experience at the Caribou Mill, Colorado. A. D. Breed, Esq., proprietor of that mill, gives the actual total cost of roasting and chloridizing at $5.50 per ton. This low cost renders it feasible to work with profit very low-grade ores.

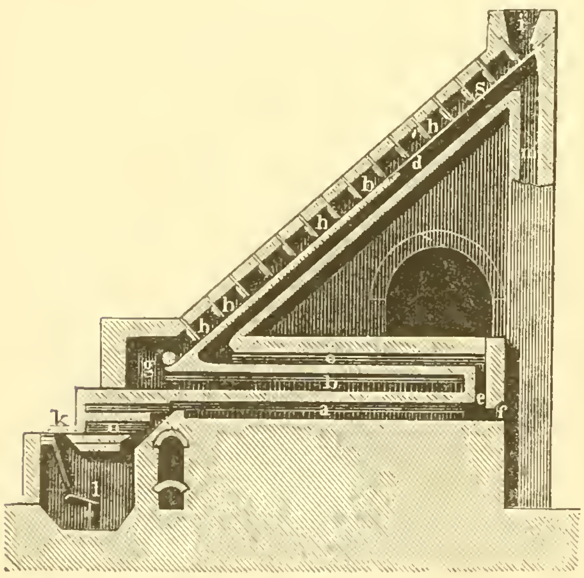
*Zinc-roasting Furnaces.*—Fig. 1891 represents a vertical section of an improved zinc-ore roasting and calcining furnace designed by Prof. Pierre de P. Ricketts. The muffle furnace on the right is 42 feet long by 17 feet wide outside. The sole of the muffle measures 39 by 14 feet, and the height of the arch in the middle is 2 feet 4 inches. There are four flues separated from each other by 9-

1891.

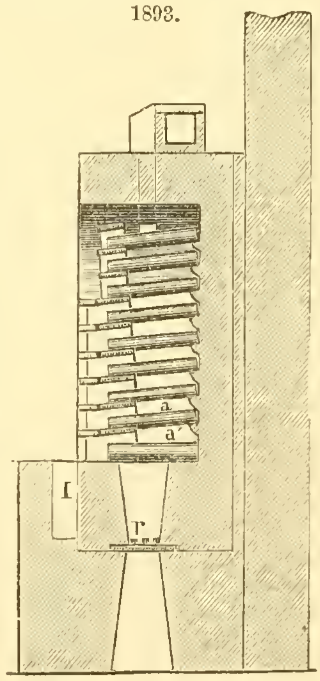


inch walls at the end farthest from the fireplace. These flues connect with a horizontal cross-flue running along the end of the furnace. This, by means of another flue at right angles to it, communicates with the calciner on the left. It is also connected by a vertical flue beneath it with the main flue underground. One of these furnaces is calculated to roast 3 tons of ore in 24 hours, with a consumption of 2 tons of coal. Should, however, the ore on reaching the end of the muffle not be completely roasted, it can be taken out and the roasting completed in the reverberatory furnaces used for calcining. The ore is charged through the opening in the arch of the muffle upon the sole below, where it remains 16 hours, 8 in passing from the charging-door to the middle, and 8 in passing from the middle to the discharge-doors. During this period it is constantly turned over. The sulphurous acid formed during the roasting is conveyed away by two flues at the end of the muffle which

1892.



1893.



connect with the horizontal underground flue. The roasting furnace can be disconnected from the calciner at any time by dampers placed at the junction of the flues.

The Hasenclever furnace, in its latest form, with which the name of Hilbig also is associated, is used at several European works. In the sectional sketch, Fig. 1892, $i$ is the hopper into which the ore is charged; $s$, an inclined channel, depressed 33° from horizontal, 1.8 metre wide, 0.5 metre high, and 9 metres long, heated from below by the flame in the flue $d$ from around the muffle furnace $b$; $h$ $h$, 50 partitions, which stop short several centimetres above the inclined floor, forcing the ore to descend in a thin layer, while the gases from the muffle $b$, passing through openings placed zigzag in these partitions, are made to traverse the surface of the ore for a long distance, and finally allowed to escape at $s$, loaded with sulphurous acid. The inclined channel and the flues are accessible through side doors. At $g$ is a hollow, air-cooled, revolving feeder, operated periodically by a water-power, at each turn of which a certain amount of ore is taken from the bottom of the incline and pushed into the muffle, while the layer of ore in the incline slips downward. Every two hours the ore is spread

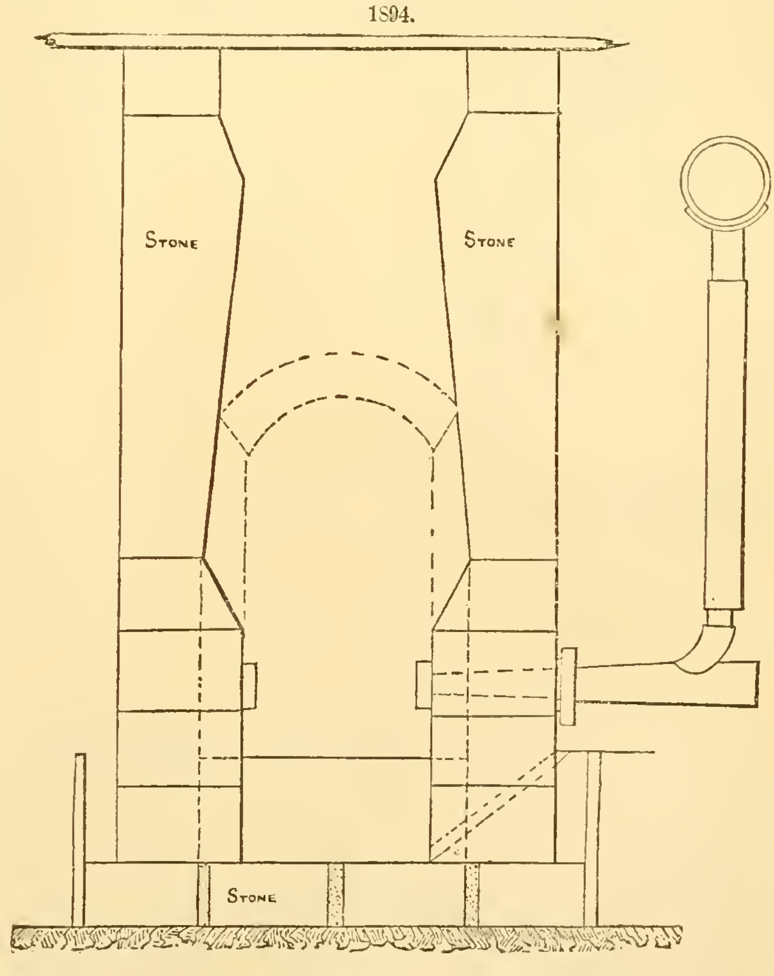
out in the muffle by hand, through working-doors, and gradually pushed to the back, where it falls through an opening upon the hearth *a*, heated by direct flame. Here it is completely roasted, the last portions of sulphurous acid escaping with the gases of combustion through *c*, *c*, *d*, and *m* into the stack. The Boetius gas-producer *l*, and the air supplied at *n*, give an economical heat to the hearth, the working-door of which is at *f*. It will be seen that this arrangement keeps the flame, gases, smoke, etc., separate from the charge till the roasting is nearly complete, and thus furnishes sulphurous-acid gas of greater purity (escaping at *s*) for the manufacture of sulphuric acid. The gas passes from *s* first into a cooling chamber, on the iron top of which ore is dried, thus completing the utilization of the heat. Even blende poor in sulphur (which is the hardest to roast) can be successfully treated in this apparatus. A blende containing 20 per cent. of sulphur when charged was found to contain at *g* 10 per cent., at the back side of *b* 6.4 per cent., and at the fire-bridge of *a* (just before withdrawal) 1.2 per cent. The further dimensions of the furnace are, in metres: muffle, *b*, 6.5 long, 1.8 wide, 0.4 high, with five working doors on one side; hearth, *a*, 5.7 long, 0.4 high; generator, *l*, 1.5 high, 0.5 broad at the bottom, 1.4 at the arch.

The Belgian system of distillation is conducted in inclined cylindrical retorts, disposed in rows above the fireplace, and provided with fire-clay nozzles or condensers, over the outer ends of which conical tubes (balloons, caps, or "prolongs") of sheet-iron are placed during the operation. The ordinary form is shown in Fig. 1893, which presents a section from front to rear. In this furnace the eight retorts *a′* of the lowest row are left empty, to serve as "protectors" and regulators of the temperature, by means of openings in them, through which the flame may be drawn at will. Above them are 61 useful retorts, *a*.

*Stone and Water-Jacket Furnaces.*—There are many ores of silver carrying gold that are too refractory to be treated as free milling ores, by amalgamation in the mortars of the battery where they have been crushed, or by the Washoe process, where the ore, after it has passed the battery screens, comes in contact with quicksilver in the pans, with the formation of an amalgam, which is afterward separated from the earthy matter in settlers. Neither can they be treated by the dry process, where the ore crushed dry in the battery mortars is elevated to the top of a Stetefeldt roasting furnace, to be sifted in a fine powder with salt down through the chloridizing shaft. Consequently resort must be had to some other method of separation.

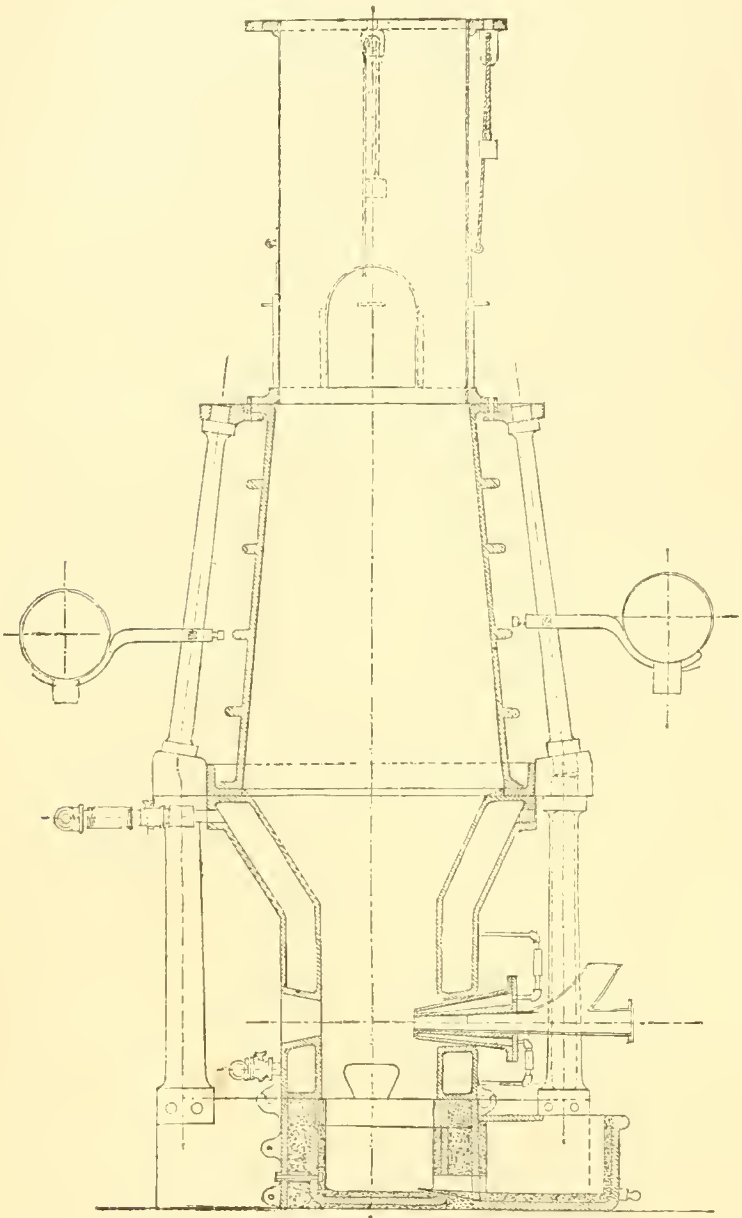
The process which, although but a few years in operation, seems to have met with the greatest success and favor, is that of treating base ores with a certain per cent. of litharge as a flux, if they do not already contain sufficient lead for slagging off. In this way a bullion is formed, which collects and retains the precious metals. Two general styles of furnaces have been adopted, termed distinctively the stone furnace and the water-jacket, called by some the hydro-cycle. The stone furnace, as shown in Fig. 1894, is commonly built of sandstone or other easily-worked stone that can be obtained in the vicinity, the upper structure resting securely upon corner-piers from 24 to 30 inches square. Springing from these are arches over the tuyere embrasures, which are constructed so as to admit of the use of from four to eight tuyeres on the sides and one opposite the slag-pot. The interior lining is either of fire-stone or fire-brick, requiring as a rule not less than 200 cubic feet of material. The bottom of the well is sunk from 12 to 18 inches below the point of slag discharge, to hold about 6 tons, and the tuyeres are located about 15 inches above the same. The lead with silver is ladled out of the metal well on the side. At a height of from 18 to 36 inches above the tuyeres an offset or contraction occurs, although the feeding-floor is generally placed not less than 12 feet above this point. The stack is commonly run up to a height of 50 feet. Such a furnace, to treat from 50 to 60 tons per day, will cost from $6,000 to $15,000, according to location. This is not meant to include the cost of erecting a light iron flue-connection to flue-stack to collect the dust, which frequently amounts to 15 per cent. of the ore treated, and assays, according to the original value of the ore, from $5 to $100 per ton. A number of managers pursue the plan of working it over, mixed with clay, to a mortar, to aid in fluxing; while others, considering it too

1894.



expensive to handle, throw it out as a waste product. The most essential points to be looked after in the running of a furnace are: first, to feed uniformly, and the proper portions of ore, litharge, limestone, and iron ore to secure an even working and no loss; second, to blow just enough air into the furnace through the tuyeres to support a combustion that will prevent clogging in the shaft, or on the other hand cutting the lining away; third, to provide an excess of power for an emergency.

1895.



The water-jacket furnace, Fig. 1895, consists of a wrought-iron stack resting upon a cast- or wrought-iron frame about the combustion-chamber, so arranged, in sections of five or more, that when one gives out it can be replaced without disturbing the rest. In each of the sections the water circulates independently of the rest, and after reaching a temperature of about 175° F. it passes over the spout into the tank below, from which it is pumped to a tank set so as to secure a head of about 12 feet above the bottom of the jacket, where the water is admitted. The interior dimensions and capacity for ore treatment are about the same as in the stone furnaces. This furnace gives most excellent results when first blown in, and would continue to do so under careful management; but carelessness and irregularity in feeding, with frequent changes of charge, soon necessitate repairs or renewals of portions damaged or destroyed. The advantages which it possesses over the other style, and which have led to its more general adoption, are that it costs only about one-third as much as a stone furnace of the same capacity; that it can be erected in locations where suitable building materials are scarce; that it can be repaired without pulling the furnace to pieces; and that it requires less labor for working. Many ingenious devices have been added to the furnace with the view of returning the valuable flue-dust immediately and continuously to the furnace or to the feeding-floor, where it can be mixed with just sufficient moistened clay to bring it under the action of the reducing flame.

In the table below are given results from a number of experiments with these two kinds of furnace:

*Table showing Results of Working of Stone and Water-Jacket Furnaces.*

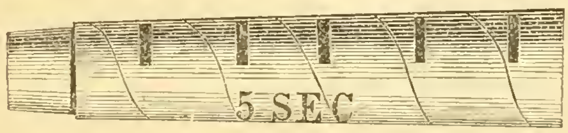
| DETAILS. | Stone. | Water-Jacket. | DETAILS. | Stone. | Water-Jacket. |
|---|---|---|---|---|---|
| Shape | Oblong. | Round or oval. | Temperature of water | 120° to 180° | 125° to 175° |
| Size of lead-well | 3½ to 4 by 5 to 6 ft. | 40 to 48 by 48 to 56 in. | Height of stack | 50 ft. | 50 ft. |
| Capacity | 5 to 6 tons. | 6 to 6½ tons. | Diameter of stack | 3 × 3 ft. | 36 in. |
| Tuyeres above slag-discharge | 15 in. | 15 in. | Life of furnace | 4 to 6 months. | 3 to 8 months. |
| Bottom of well below | 18 to 24 in. | 18 to 24 in. | Length of dust-flue | 800 ft. | Downcast. |
| Height of combustion-chamber | 36 to 56 in. | 42 to 54 in. | Cost | $6,000 to $15,000 | $2.000 to $5,000 |
| Height of feed-floor | 12 to 15 ft. | 12 to 15 ft. | Tons of ore worked per 24 hours | 40 to 50 | 30 to 45 |
| Thickness of water-jacket | .......... | ⅜ to ½ in. | Bushels of charcoal per ton | 30 to 40 | 25 to 30 |
| Number of tuyeres | 5 to 9 | 4 to 8 | Bushels of coal daily | 1.200 to 2.000 | 750 to 1,350 |
| Size of tuyeres | 3 in. | 3 in. | Cost of charcoal per bushel | 18 to 30 cts. | 18 to 30 cts. |
| Length of tuyeres | 15 to 30 in. | 20 to 30 in. | Weight of coal per bushel | 18 lbs. | 18 lbs. |
| Pressure of air | 1⅕ to 1½ | 1⅛ to 1½ | Tons of ore-escape daily | 15 to 18 | 10 to 15 |
| Cubic feet of air-discharge | 4,400 to 6,400 | 4,500 to 7.000 | Percentage of escape | 10 to 15 | 10 to 15 |
| Diameter of air-pipe | 12 in. | 12 in. | Assay of dust | Gold, $10 to $40; Silver, $10 to $30 | .......... ......... |
| Gallons of water daily | 12,000 to 16,000 | 12,000 to 15.000 | Waste in slag and speiss | 75 per cent. | 75 per cent. |
| | | | Cost of smelting, per ton | $9 to $15 | $8 to $12 |

In the stone furnace the result from a charge of 500 lbs. of ore and 250 lbs. of coal and fluxes would be about 20 per cent. of metal, 10 per cent. of dust, 60 per cent. of slag, and 10 per cent. of speiss. F. H. McD. (in part).

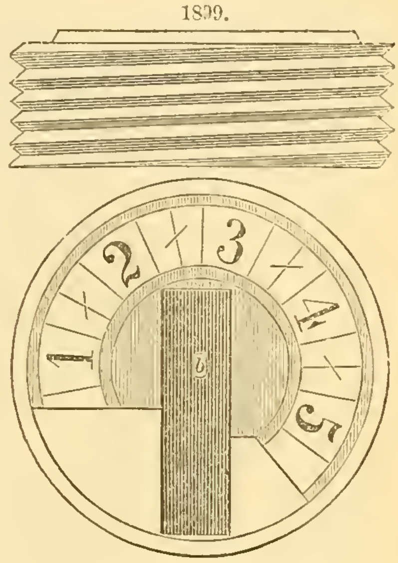
FUSES. Devices used to ignite the bursting-charges of hollow projectiles at any desired moment of their flight, or to communicate fire to the explosive in a mine or blast. As used for projectiles, they are of three kinds, viz.: time, percussion, and concussion fuses.

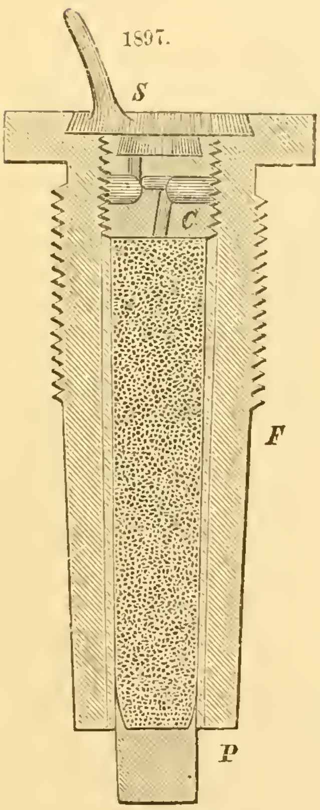
Time Fuses.—The time fuse consists of a column of inflammable composition which, being ignited by the charge in the gun, burns for a certain space of time, at the end of which it communicates its flame to the bursting-charge in the shell. The navy time fuse, represented in Fig. 1896, is composed of a mealed-powder composition driven into a paper case. This case is inserted in a metal stock, *F*, Fig. 1897, which is screwed into the fuse-hole. A safety-plug, *P*, at the lower end, prevents the communication of fire to the powder in the shell, in case of the accidental ignition of the fuse. The jar of concussion consequent upon the explosion of the charge in the bore of the gun is so great as to detach the plug from the case, so that from the moment the shell leaves the gun the communication is open between the burning composition of the fuse and the bursting-charge in the shell, and as soon as the composition is consumed the shell explodes. *C* is the water-cap, made of copper. On the outer surface of this are pieces of quick-match, the fire from which, when ignited by the explosion of the charge in the gun, communicates to the powder in channels

1896.

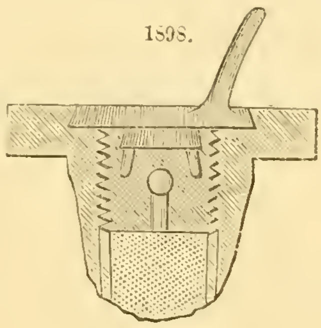



1899.

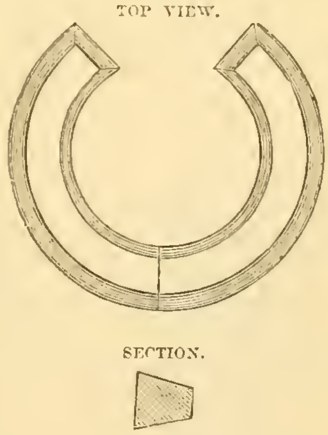



1898.



1900.
TOP VIEW.



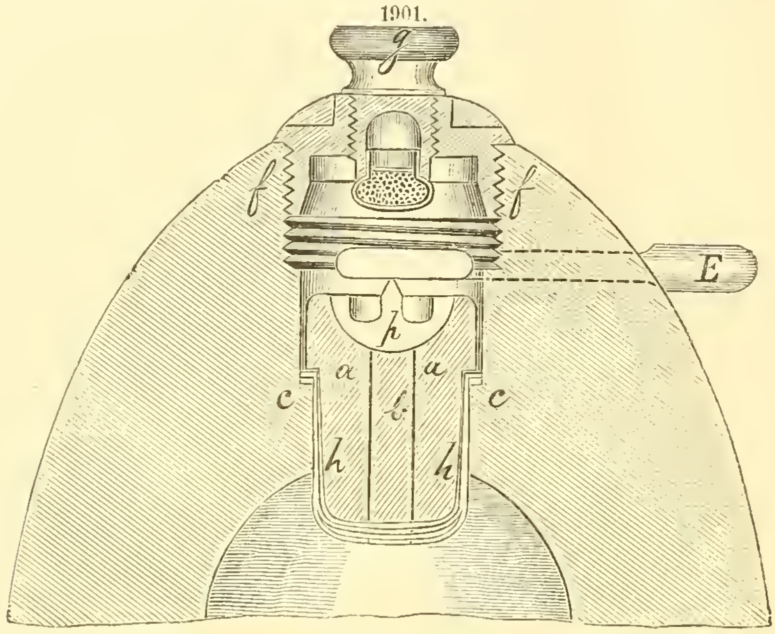

in the cap, and so to the bursting-charge in the shell. The object of the water-cap is to prevent the entrance of any matter, such as sand or water, over which the shell may ricochet. The safety-cap, *S*, is a leaden patch which covers the top of the fuse, and is removed before the shell is inserted in the gun.

*The Bormann Fuse*, represented in Figs. 1899 and 1900, consists of a lead-alloy disk, with an interior canal in which the burning composition is condensed. The upper surface of the disk above the composition is very thin, so as to yield readily to the cutting tool employed to open it, its whole external surface corresponding of course to the composition below. It is graduated into seconds and quarter seconds. The end of the composition at which the enumeration begins communicates with a small magazine at the centre of the disk, which is charged with grained powder and closed on the inner side with a very thin disk of lead, so as to yield in that direction to the explosion. The thin covering above the composition is cut so as to lay bare the upper surface of the latter and afford the flame access to it at the part desired. The composition occupies the assigned time in passing from the incision toward the origin of the graduation, when it traverses the magazine, the contents of which explode toward the interior, and so fire the charge in the shell.

Percussion Fuses.—A percussion fuse is one which is prepared for action by the discharge, and put in action by the shock on striking the object. The essential requirements of the device are that it shall not be ignited by the shock of discharge or on striking the water, that it shall be ignited by the impact of the shell against the object, and that it may not be liable to explode by handling or during transport.

*The Shenkle Fuse.*—This is the form used in the U. S. navy. It consists of a metal fuse-stock inclosing a movable core-piece or steel plunger bearing a musket-cap. The plunger is confined inside the stock, in which it fits loosely, by a screw or pin which passes through both stock and plunger, and so prevents motion of the latter. When the projectile is fired, the plunger by its inertia carries away the pin and presses against the bottom of the fuse-stock. When the motion

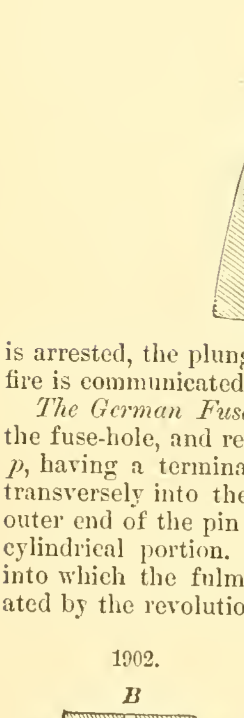
1901.



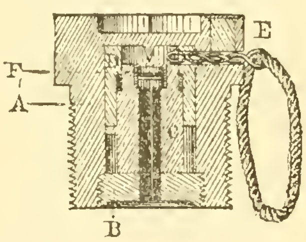

is arrested, the plunger continuing on strikes the safety-cap in front of it, the cap is exploded, and fire is communicated to the bursting-charge.

*The German Fuse*, Fig. 1901.—In this fuse a plunger *a h*, having a central fire-hole *b*, is let into the fuse-hole, and rests against the shoulders *c c*. This plunger is surmounted by a perforated cap *p*, having a terminating point above. The plunger is retained in place by a pin *E*, which passes transversely into the fuse-hole, the side of which is put in contact with the point of the cap. The outer end of the pin projects on the side of the shell, the projection being limited by the line of the cylindrical portion. The fuse-hole is closed by a screw-cap *f f*, having a small central screw-hole into which the fulminate cap *g* is screwed. When fired from a rifle, the centrifugal force generated by the revolution of the shell throws out the pin *E*; the plunger by its inertia is retained at the bottom of the chamber during the flight of the projectile; at the moment of impact the plunger impinges against the fulminate, which exploding ignites the charge in the shell. To keep the bursting-charge in place in the shell, a brass thimble *h*, with a flange on top and a small hole in the bottom, is first pressed into the fuse-hole and takes against the shoulder *c*.

1902.




1903.




*Hotchkiss's Fuse*, Fig. 1902, consists of a metal body *A*, closed at the front end with a screw-cap *B*. It has a conical hole at the rear, which is closed by a lead safety-plug *C* pressed in very tightly, so that the plug projects a little through the base of the body-case toward the inside. The plunger *D* is composed of lead cast into a brass casing to strengthen it, and to prevent the lead from being upset by the shock of discharge. Two brass wires *E F*, cast into the lead on opposite sides of the plunger, hold it suspended in the case, the wires going through the holes in the bottom of the case, and being held securely in position by the safety-plug. The plunger has a nipple cast into the lead, and is primed with an ordinary percussion cap; in its axis it has a powder-chamber *G*, containing the igniting charge. The operation of the fuse is as follows: The safety-plug is dislodged backward into the interior of the projectile by the shock of discharge; the wires then being not held tight in the hole, the plunger is disengaged and rests on the bottom of the fuse-case, and is free to move in the line of axis. When the flight of the projectile is suddenly retarded by its striking any object, the plunger, in consequence of its inertia, is driven forward, and the primer strikes against the screw-cap, thus igniting the powder in the channel, and so firing the bursting-charge of the projectile.

*The English Royal Laboratory Fuse*, Fig. 1903.—This fuse consists of the following parts: *A*,

the brass stock or body; *B*, the brass screw-plug closing rear end of fuse; *C*, the lead plunger; *D*, the brass thimble; *E*, the brass safety-wire; and *F*, fulminate. The body has a solid head, having on the outside a square recess for the fuse-wrench, and on the inside a sharp pin projecting from the centre. The screw-plug *B* has a hole through its centre which is covered by a thin disk of brass secured on by solder; two small recesses in the bottom of the plug facilitate its insertion with a wrench. The lead plunger *C* has also a central hole through it, in the front end of which is placed the fulminate cap; the plunger has also two slight projections from its sides, upon which rests the brass thimble *D*. Running through holes in the heads of the fuse-body and thimble, and to one side of the centre and resting on top of the plunger, is the twisted safety-wire *E*. In order to prevent the easy withdrawal of the safety-wire, a small hole is bored into one side of the fuse-body and down to the hole through which the wire is inserted, and into this is poured melted lead. A strong cord facilitates the extraction of the wire before firing. Inserted in a loaded shell with the safety-wire removed, and meeting with a resisting object in flight, the plunger is thrown forward, sheering off the shoulders; the fulminate, striking the pin, is ignited, the brass disk closing the hole through the screw-plug is blown out, and the bursting-charge of the shell ignited.

For reports of tests of fuses, see "Report of Chief of Ordnance, U. S. A.," 1878. The following percussion fuses are recommended as superior to all others: German, Hotchkiss, English Royal Laboratory, and Shenkle; this being the order of merit.

Concussion Fuses.—A concussion fuse is one which is put in action by the discharge, but the effect of that action is restrained until it strikes any object. The distinction between percussion and concussion fuses is somewhat arbitrary, and the application of the terms has depended in large measure upon the sense in which the inventor of any particular fuse chooses to apply them. Such a fuse, in order to be serviceable, must not only produce explosion on striking, but it must not produce it on the shock of the firing of the gun charge, nor on that produced by the ricochets of the projectile in or out of the gun. These fuses have usually consisted of some composition of the highly explosive fulminates, and the extreme danger of using them has been the chief obstacle to their adoption.

*The Splingard Fuse*, Fig. 1904, is both a concussion and a time fuse. The appearance of the paper case is similar to that of the Navy time fuse, but the internal arrangement is different. The case is filled with fuse composition, and a long cavity is formed in the lower portion of the composition by driving it around a spindle as in a rocket. This cavity is filled with moist plaster of Paris, and a long needle is inserted in it, nearly to the bottom of the plaster, forming a tube inclosed in and supported by the composition. The latter is ignited in the usual way at the top, and as it burns away leaves a portion of the plaster tube unsupported. When the shell strikes its object, the stock breaks off the unsupported part of the tube, and the flame of the composition immediately communicates with the bursting-charge; if the tube does not break, the composition burns and the bursting-charge is ignited as an ordinary time fuse.

*The Bacon and McIntyre Fuse*, Fig. 1905, is very similar to the foregoing, except that the internal tube is differently formed. *A* is an outside paper case; *B*, the powder composition; *C*, inside paper case; *D*, coating of plaster of Paris; *E*, conical tube; and *F*, a ball on the tube. The thin copper tube *E* extends through the centre of the fuse composition, and has a solid copper head *F*, secured in its upper end by a little soft solder. The fuse being ignited by the flame from the gun, the upper part of the composition burns away in the first second or two of time, melting the solder and leaving the head of the tube free to be displaced by the shock of impact. Under ordinary circumstances this fuse acts like the time fuse, the stopper *F* being kept in place by the plaster of Paris; but upon impact the plaster breaks, the ball falls, and the flame, passing through the tube, at once ignites the bursting-charge.

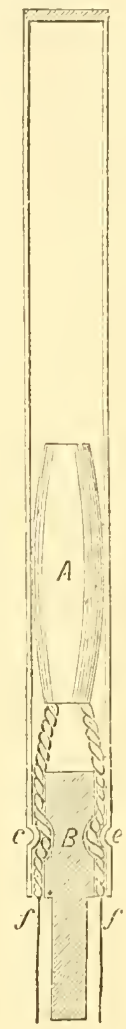
Electric Fuses or Exploders, for mines, etc., may be divided into two classes: those in which the heat is obtained by the passage of the electric spark over a break in the circuit, and those in which the heat is obtained by the passage of the current over a conductor of great resistance. The first, called tension fuses, may be used with the Leyden jar, induction coil, or any static electrical machine. All that is necessary for a fuse or exploder of this class is, that there shall be a break in a circuit not greater than the spark can easily be made to pass over (one-sixteenth to one-thirty-second of an inch is the usual distance), and that between the two points of the break shall be placed some composition that will be ignited by the passage of the spark. Gunpowder can be so fired, if packed closely between the points; but it is better to use some more sensitive material as a priming. Fulminating mercury is fired by the spark, and may be used for this purpose, either pure or mixed with other substances, as in percussion-cap composition. Abel's composition has thus been used. It is composed of subsulphide of copper 64 parts, subphosphide of copper 14 parts, and chlorate of potash 22 parts. The wires of the fuse must be firmly held in a wooden block or similar contrivance, in such a manner that the priming cannot be displaced, nor the distance between the points altered. Outside the priming material is placed fulminating mercury, gunpowder, or other substance, and the whole is properly inclosed in a wooden or metallic case. The principal difficulty connected with the use of statical electricity for causing explosion is the high insulation of the conducting-wires that is required. If the insulation is imperfect, the loss is so great as to render the firing of the fuse uncertain or impossible.

The second class of electric fuses or exploders are those in which, by the passage of the current, a portion of the circuit having a great resistance becomes sufficiently heated to ignite some explosive or inflammable body in contact with it. These fuses are used with the voltaic battery and the various dynamo-electric machines, such as Farmer's, Gramme's, etc. For convenience they may be divided into two classes: those in which plumbago, copper sulphide, Abel's composition, or other similar highly-resisting substance forms the part of the circuit which is to be heated; and those in which a fine platinum wire or other comparatively good conductor occupies that position.

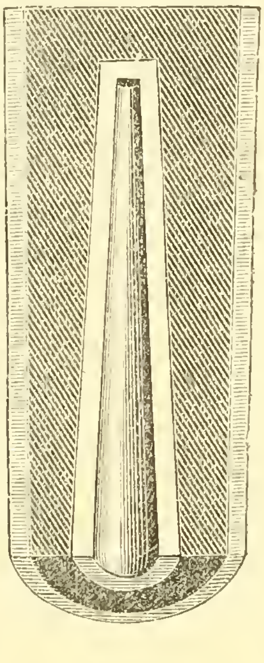
Of the first division are the fuses used in connection with Wheatstone's machine and others similar. They consist essentially of a break in the circuit, which is bridged by a layer of plumbago or composition which has a certain conducting power, and which will burn when heated. In contact with this is placed the gunpowder, fulminating mercury, or other substance which is the charge of the fuse. The difficulties connected with the use of these fuses and the machines for which they are made are, that good insulation of the leading-wires is necessary, and that this, from various causes, is often uncertain. Safe fuses of this sort may be made, since no very sensitive composition is required as a priming.

Of the second division are those known as platinum or German-silver wire fuses. The essential point in the construction of these is the placing of a short piece of very

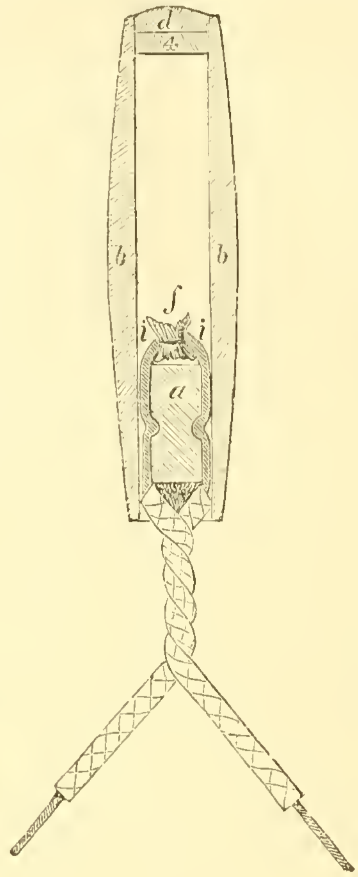
1907.



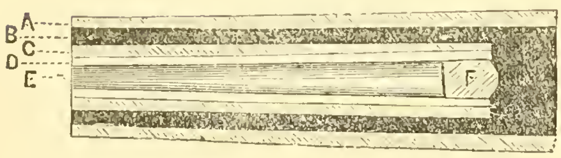

1904.



1906.




1905.




fine platinum or German-silver wire in the circuit, and in contact with it a priming material which when fired ignites the fuse-mass; or the wire may be imbedded in the fuse-mass itself, and thus inflame it directly without the intervention of a priming. This form of electric fuse has many advantages. The current with which it is used is one of great quantity and low intensity, so that the insulation of the conducting-wires need not be as complete as in the other cases. In fact, no insulation is required if the fuse is sufficiently delicate and the whole circuit is not too long.

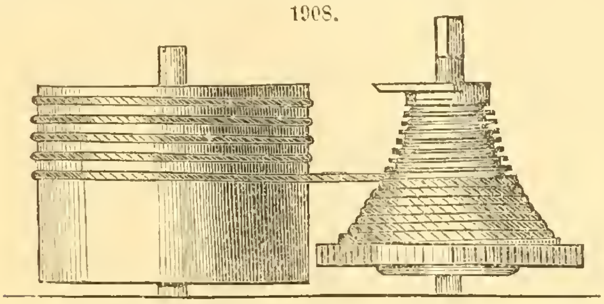
*The Dynamo-Electric Igniter* used in the U. S. navy is represented in Fig. 1906. It consists of a hard wooden plug *a*, half an inch in length and about three-sixteenths of an inch in diameter, having a score cut about its centre, and a longitudinal groove on each side for the reception of the copper wires. The latter are cotton-covered, and are twisted together for about an inch, and stripped of their insulation almost to the twist. The uncovered parts of the wires are pressed firmly into the grooves in the sides of the plug, and are cut off so that they project about one eighth of an inch above the plug. The ends of the wires are now split with a very fine saw in the direction of the plane passing through them, and the distance between the ends is carefully adjusted to three-sixteenths of an inch; after which platinum wire No. 40 is stretched between them to form the bridge, and is securely soldered to the ends of the split wires *i i*. A wisp of gun-cotton *f* is next wrapped around the platinum wire, and the ends of the copper wires are pinched together sufficiently to take all strain from them. The plug is inserted in a hollow wooden case *b b*, 2 inches long, and is countersunk one-eighth of an inch. The resistance of the wire should not vary five-tenths either side of 0.42 ohm. The upper part of the case is filled with rifle-powder, the top being closed with a disk of cork, over which is poured some water-proof composition, and the whole is properly coated with shellac.

*The Dynamo-Electric Fuse*, Fig. 1907, is made by inclosing one of the igniters above described in a stout paper case about 6 inches in length, which is filled with rifle-powder to give more flame and consequently a better ignition of the charge. One end of the case is closed by a wooden plug *B*, with grooves cut in the sides for the wires, which serves for the bottom, and the other end is filled with a disk of cork coated with collodion.

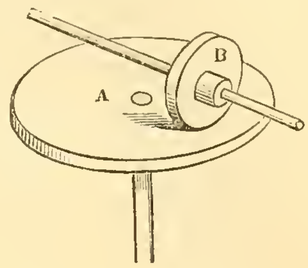
The foregoing is mainly abridged from "Naval Ordnance and Gunnery," Cooke, New York, 1875. See also BLASTING.

FUSEE. A mechanical contrivance chiefly used in chronometers and watches, in order to maintain a uniform force upon the train of wheels, and to compensate for the decreasing power of the spring. The spring is inclosed in a cylindrical barrel, and sets the wheels in motion by the aid of a

1908.

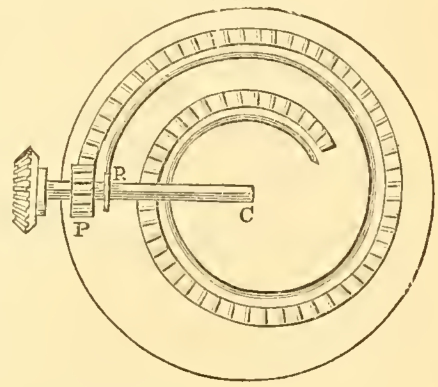


1909.




cord or chain wound partly upon the barrel and partly upon a sort of tapering drum called a fusee, Fig. 1908. As the spring uncoils in the barrel, the pull of the cord decreases in intensity; at the same time, however, the cord unwinds itself from the fusee, and continually exerts its strain at a greater distance from the axis, that is, with a greater leverage and with more effect.

1910.




The *disk and roller*, Fig. 1909, equivalent to the fusee, consists of a disk *A*, revolving round an axis perpendicular to its plane and giving motion to a rolling plate *B*, fixed upon an axis which intersects at right angles the axis of the disk *A*. Supposing the rotation of the disk to be uniform, that of the roller *B* will continually decrease as it is shifted toward the centre of *A*, and conversely. This is precisely the effect produced by a fusee. The roller may be a wheel furnished with teeth, and may roll upon a spiral rack as shown in the diagram. As the disk revolves, the pinion *P*, Fig. 1910, slides upon the square shaft, and is kept upon the rack by the action of a guide-roller *R*, which travels along the spiral shaded groove.

GALVANIC BATTERY. See Electro-Galvanic and Thermic Batteries.

GALVANOPLASTY. See Electro-Metallurgy.

GAS, CARBONIC ACID. Carbonic acid gas is composed of 1 atom of carbon and 2 atoms of oxygen. Its chemical symbol is therefore $CO_2$. Compared with air its weight is as 1.529 to 1. Of the gases which may be liquefied, carbonic acid is the best for use as a source of motive power. It can be readily prepared by pressure in liquefied form, and stored in strong vessels of small compass. The following table by Regnault shows the tension of the liquid in atmospheres at various temperatures Fahrenheit:

| Temperature. | Volume. | Temperature. | Volume. |
|---|---|---|---|
| − 13° | 17.1 | + 59° | 52.1 |
| − 4° | 19.9 | + 68° | 58.8 |
| + 5° | 23.1 | + 77° | 66.0 |
| + 14° | 26.7 | + 86° | 73.8 |
| + 23° | 30.8 | + 95° | 82.1 |
| + 32° | 35.4 | + 104° | 91.0 |
| + 41° | 40.4 | + 113° | 100.4 |
| + 50° | 46.0 | | |

The specific gravity of liquid carbonic acid is as follows:

| Temperature. | Sp. Gr. | Temperature. | Sp. Gr. |
|---|---|---|---|
| − 4° | 0.90 | + 86° | 0.60 (Thilorier) |
| + 32° | 0.83 | + 32° | 0.9470 (Andréeff) |

The expansion of liquid carbonic acid with temperature is at

| Temperature. | Volume. | Temperature. | Volume. |
|---|---|---|---|
| + 4° | 0.9517 | + 50° | 1.0585 |
| + 32° | 1.000 | + 68° | 1.1457 (Regnault) |

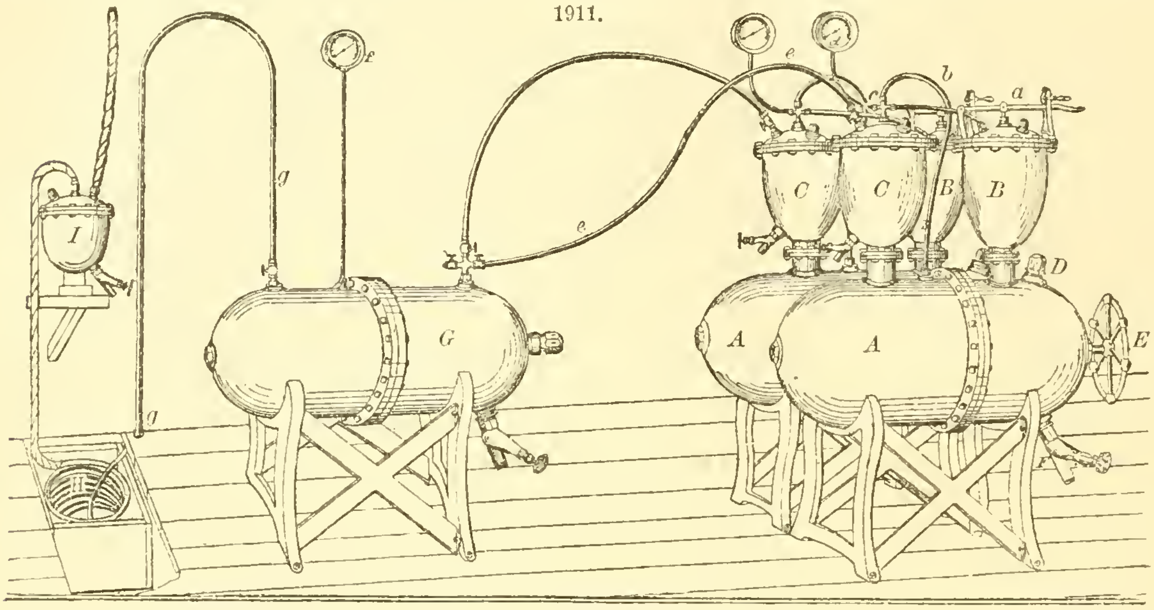
*Carbonic Acid Gas as a Motor.*—Carbonic acid gas has been employed for driving the propelling engines of torpedoes; and experiments in liquefying it, and storing it in flasks, to adapt it for this purpose, have been carried on at the United States Torpedo Station at Newport, R. I. The following details* on the subject have been prepared and published by Mr. Walter N. Hill, S. B., chemist of the station. The liquefying apparatus constructed by Mr. Hill is represented in Figs. 1911 and 1912. The compressing-pump used is a modification of the Burleigh air-compressor. The generating

* Published by permission of the author.

apparatus was obtained from John Matthews of New York, and is that much used for generating carbonic acid gas for making soda-water, with some alterations and additions to render it serviceable for this purpose.

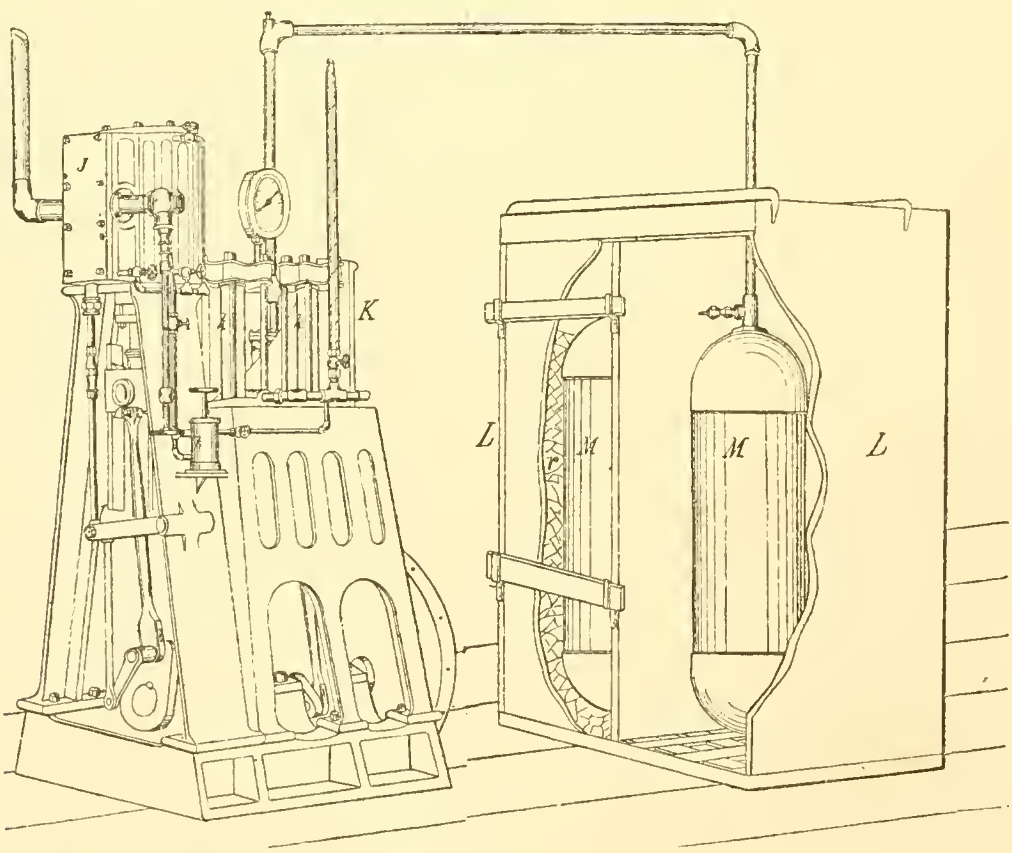
Fig. 1911 shows the generators, the vessel for receiving, and the coil for cooling the gas. Fig. 1912 shows the compressing-pump and the receivers or flasks, into which the gas is condensed. As used,

1911.




the whole forms one complete apparatus, and the gas generated in one end is obtained in the liquid condition at the other. There are two generators, so that while one is in action the other may be emptied and recharged. *A* is a large cast-iron cylinder with rounded ends. This receives the marble-dust, from which the gas is obtained, and water. *E* is a wheel by which is revolved a composition agitator within the cylinder. *F* is a large valve, through which the spent charge is drawn off. The acid (sulphuric) is contained in a small cast-iron vessel *B*, which is supported by a projection cast on *A*. There is a small opening in the bottom of the acid-receiver *B*, which is continued

1912.




through the projection on *A*. This is closed by a plug on the end of a rod, which passes up through a gland on the top of *B*. This rod is hinged to the arm *a*, so that it can be raised or lowered at pleasure; and when down, the arm *a* is prevented from rising by a cam, which works in a frame on the side. *C* is a vessel of the same size as *B*, but it has no direct communication with *A*. This contains water for washing the gas.

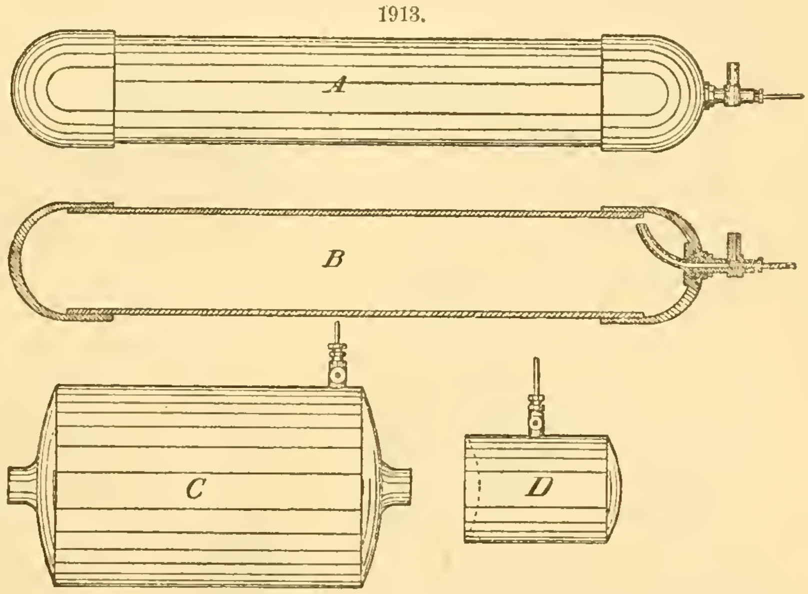
When in use, the necessary quantities of marble-dust and water are poured into *A* through an opening which is closed by the cap *D*; the corresponding amount of acid is poured into *B* through an opening, which is then closed by a cap firmly screwed on, and water put into *C*, which is also tightly closed. The plug-valve in *B* is then lifted by raising the handle *a*, and a portion of the acid allowed to run down into *A*. The valve is then closed by bringing down the handle *a*, and locking it with the cam. The acid let down into *A* acts upon the calcium carbonate (marble-dust), and generates carbonic acid gas, which passes up the lead pipe *b* to the cross *c*. To one arm of the cross is attached the pressure-gauge *d*, and to another a short lead pipe, which is connected with the top of *B* and serves to equalize the pressure in *B*, so that the valve may be easily worked. The lower branch of the cross is a pipe which extends to the bottom of *C*. The gas therefore bubbles up through the water in *C* to the upper part of that vessel. From thence, when it is to be compressed, it is drawn through the pipe *e e* to the receiver *G*.

All the castings of the generators are heavily lined with lead to protect them from the action of the acid. The valves are of brass, heavily tinned. The generators are all tested to 500 lbs. to the inch, and are capable of supporting a much heavier strain. They are limited to 300 lbs. pressure, and are provided with ingenious safety escapes.

From the receiving vessel the gas passes through a lead pipe *g g* into the coil of lead pipe *H*. This coil is placed in a tank or box under the floor, which is filled with ice-water flowing from the freezing mixture in the box *L L* mentioned below. The other end of the coil is connected to a strong small vessel, *I*.

Fig. 1912 represents the compressing-pump and the receivers for the liquid. The steam-cylinder *J* has 15 inches stroke by 7 inches diameter. There are two compressing cylinders, *k k*, of steel, each $2\frac{1}{2}$ inches in diameter by 10 inches stroke, provided with steel pistons, in which are small steel valves opening upward. The receivers or flasks *M M*, into which the gas is condensed, are placed in the box *L L*, where they are surrounded by a mixture of pounded ice and salt, *r*. During the compression, the cooling mixture must be stirred and pressed against the receiver in order to obtain as much cooling effect as possible, for upon this largely depends the pressure at which liquefaction takes place. When the flask or receiver is thoroughly cold and empty, this pressure is about 350 lbs., but rises as the operation goes on, and large quantities of gas are rapidly condensed to 500 to 600 lbs., which may be considered as the average range. Sometimes a higher pressure is attained, of 700 to 800 lbs., when the condensation is very rapid and the cooling imperfect.

1913.




Flasks to contain liquid carbonic acid are shown in Fig. 1913. They are cylinders with rounded ends. Each is provided with a valve in the centre of one head. When in place in the torpedo they lie upon their sides. The opening controlled by the valve in each is, therefore, continued into the interior by means of a pipe which turns up against the side. In this way gas passes out only when the valve is opened. They are four in number: two 7 feet long each (including valve), one 5 feet long, and one 4 feet long (both with valves included). The outside diameter of each is 12 inches along the body, and $13\frac{1}{4}$ at the heads. They are made of the finest sheet steel (.045 inch thick), in successive layers, which are firmly fastened together with pure tin. The heads are made from cup-shaped pieces of steel, which are placed one within the other and sweated together with tin. A flask constructed as explained, which was tested to destruction, gave way under a pressure of 1.4 ton (of 2,240 lbs.) to the square inch, or 3,136 lbs. Rupture occurred in the body, and the sheets themselves were torn through irregularly without regard to the joints. The heads and junctions of the heads to the body were not affected. The strains borne by these flasks may be calculated as follows: At 1,200 lbs.: longitudinal strain, 19,104 lbs.; tangential strain, 38,800 lbs. At 1,365 lbs.: longitudinal strain, 21,731 lbs.; tangential strain, 44,152 lbs. These calculations are based upon a thickness of side of .18 inch. In reality it is nearly five-eighths of an inch, but of this only the steel is of importance; and, as there are four layers, this amounts to .18 inch. The excess of tin on the inside, as already remarked, is not required, and does not add to the strength. Taking the tensile strength of the steel at the low figure of 120,000 lbs., it will be seen that the extreme strains are well below this point. Finally, the flask which gave way under 3,136 lbs. hydraulic pressure had, when it ruptured, a tangential strain upon the surface withstanding it of 101,396 lbs. to the inch.

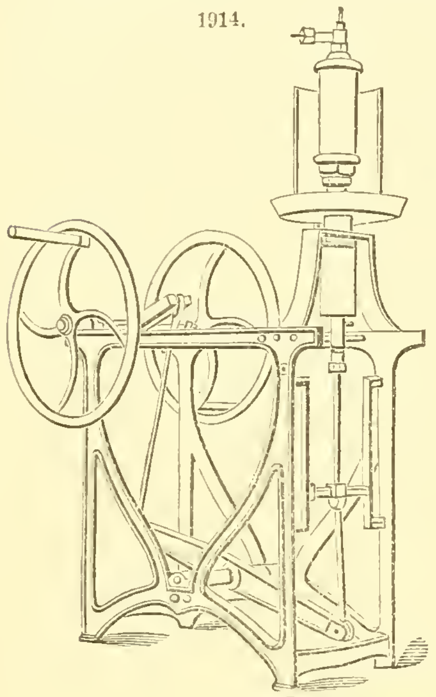
Ritchie's improved form of Natterer's apparatus is represented in Fig. 1914. In this apparatus the gas is conducted into a bronze receiver capable of resisting a pressure of 200 atmospheres, and is condensed by means of a steel force-pump. The receiver is surrounded by a copper cylinder containing a mixture of ice and salt. When enough of the gas is thus liquefied, it is caused to pass

through a tube, terminating in a fine rose of wire gauze and into a lined woolen bag. On passing out, the cold produced by evaporation is so intense as to freeze the liquid carbonic acid, which forms a deposit resembling snow. By means of the solidified carbonic acid it is possible to freeze mercury in a white-hot platinum capsule. Water placed in the latter assumes the spheroidal state, in which it does not really touch the vessel, being separated from it by a layer of steam; if, now, solid carbonic acid mixed with ether is introduced into the water, enough heat is absorbed by the evaporation of the carbonic acid to freeze a small quantity of mercury placed in the mixture.

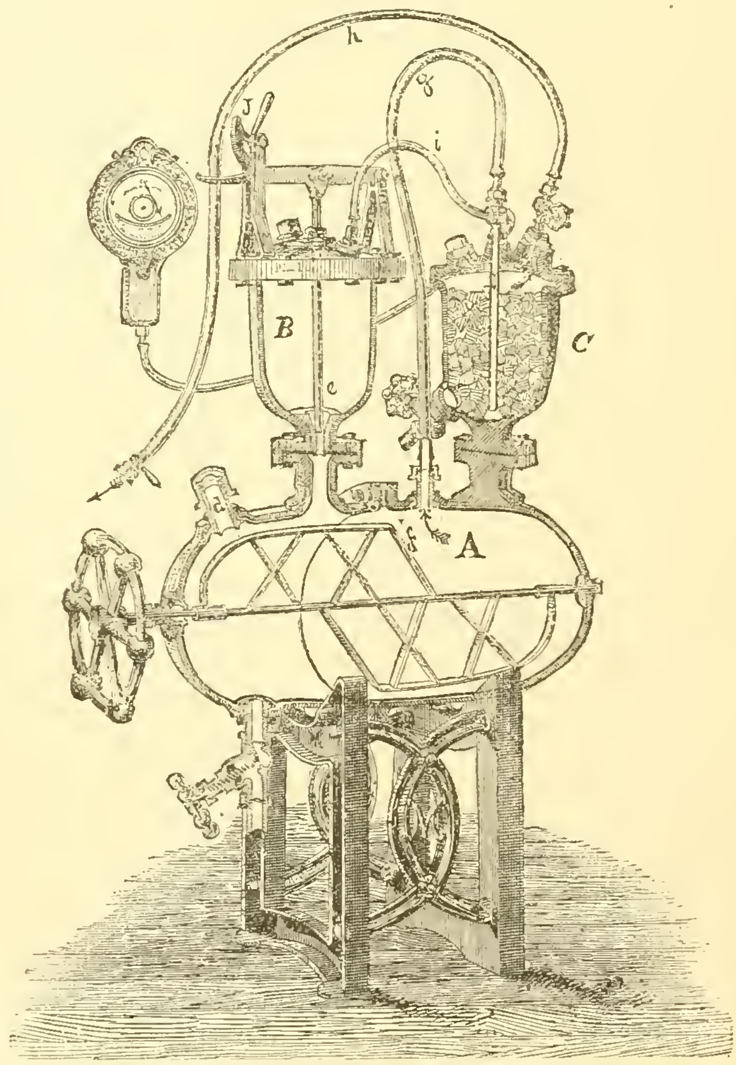
*Manufacture of Carbonated Beverages.*—There are two systems of apparatus for making "soda water" and other carbonated beverages, the continuous and the intermittent. The continuous system, being well adapted to making carbonated beverages for filling siphons and bottles, is much used in Europe, while the intermittent system prevails in the United States, where beverages are extensively dispensed from the counter.

The continuous system consists of a generator, in which the gas is evolved under very moderate pressure; a gasometer, into which the gas passes and is stored; and a beverage-carbonating compressor, by which the liquid and gas are compressed into a receiver and agitated under a pressure of from 150 to 200 lbs. to the square inch for filling siphons, or 60 lbs. for filling bottles. In the intermittent system, the

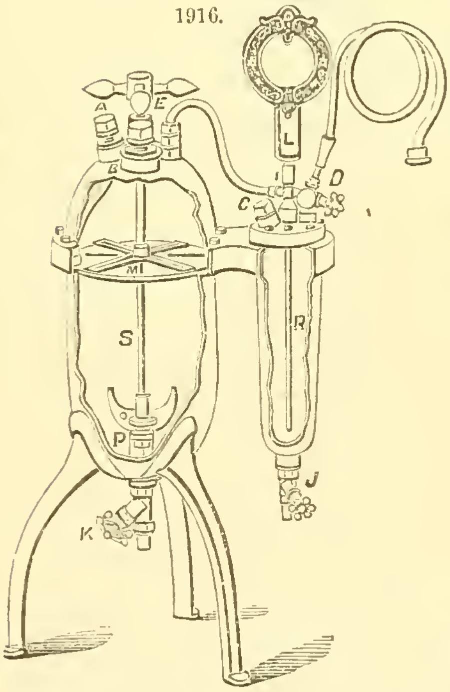
1914.



1915.




1916.




pressure is obtained in the generator from the expansive force of the gas evolved by the chemical action of sulphuric acid on a carbonate. After the required pressure is obtained, the gas is drawn into a receiver and agitated with the liquid, to carbonate it.

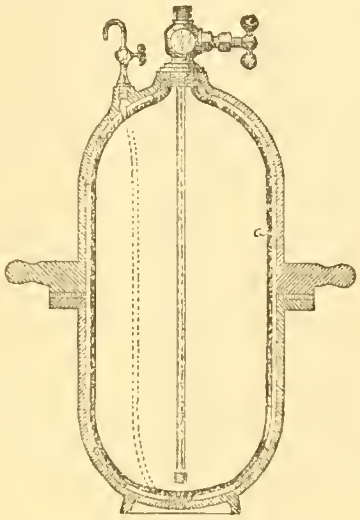
Fig. 1915 represents the Matthews generator, generally used in either system. The chamber *A* is filled with a powdered carbonate (preferably ground marble) and water to about two-thirds its capacity. Sulphuric acid is poured into the acid-chamber *B*. The gas-washer *C* is filled with chips of marble and water to wash and cool the gas. All the openings in the generator are then tightly closed. The sulphuric acid is allowed to enter the carbonate chamber *A*, by means of the valve *c*, in small quantities, and the agitator *f* is turned to mix the carbonate and water with the acid. As the carbonic acid is evolved, it passes through the pipe *g* to the bottom of the gas-washer, and rises in minute bubbles through the water and lumps of marble to the pressure-gauge. When the required pressure is obtained, the gas is drawn into the fountain by means of the pipe *h*. The pipe *i*

connects the top of the acid-chamber with the gas-washer, equalizing the pressure in the two, and thereby preventing the pressure of the gas in the chamber *A* from opening the valve *e*. The valve *e* is locked in position by means of the cam *j*.

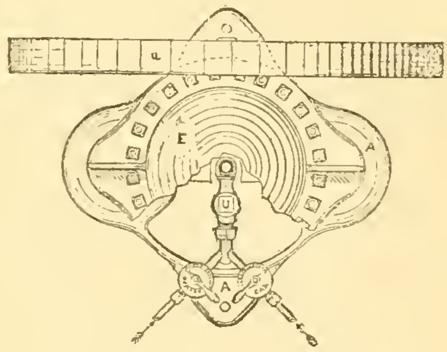
Another form of generator is shown in Fig. 1916. In this a mixture of sulphuric acid and water is introduced through the bung, and the marble-dust is poured in through *B*. The acid liquor passes

1917.

1918.

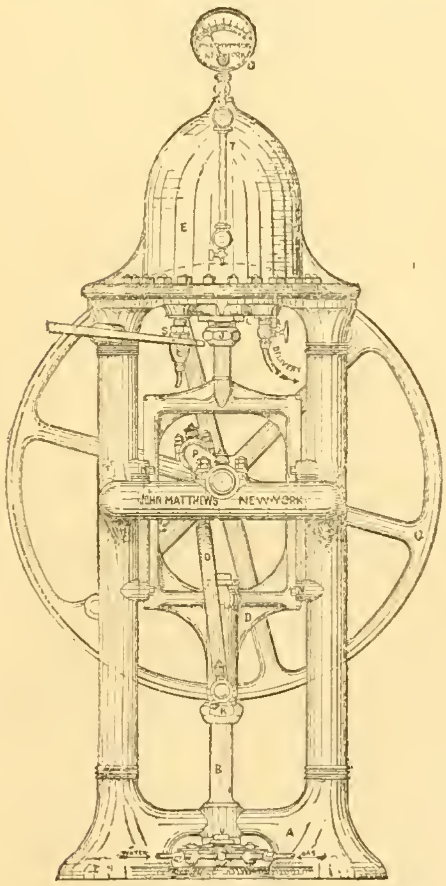


1919.



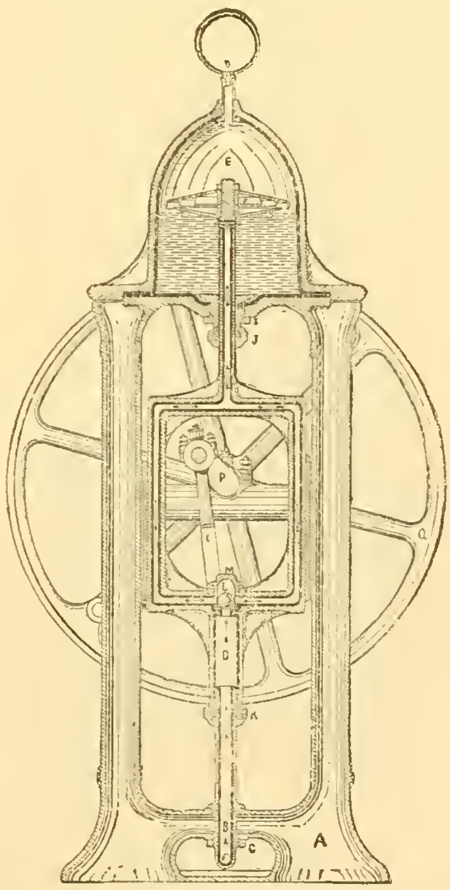
to the bottom of the vessel; but the marble-dust is arrested by a diaphragm *M*, furnished with several slits, through which the marble-dust is made to sift when the shaft *S* is caused to revolve by turning the handle *E*. At the same time the agitator *O* facilitates the evolution of gas by keeping the mixture constantly stirred. As soon as a pressure of 105 lbs., indicated by the gauge *L*, is reached, the stop-valve of the fountain is opened, and the gas is made to pass into it slowly by

1920.




FRONT ELEVATION.

1921.



SECTIONAL ELEVATION.

1922.

gradually opening the stop-valve *D* of the gas-washer. When enough gas has come over, the valves are closed, the pipe is disconnected, and the fountain is made to revolve in its frame for about ten minutes, to aid the absorption of gas by the water.

Carbonic-acid-gas generators are made either of steel, iron, or copper, and are lined with sheet lead without seams to prevent corrosion. Those made of steel are the best, as they will resist a pressure of 2,500 lbs. to the square inch. They cannot be burst by the chemical action even of a

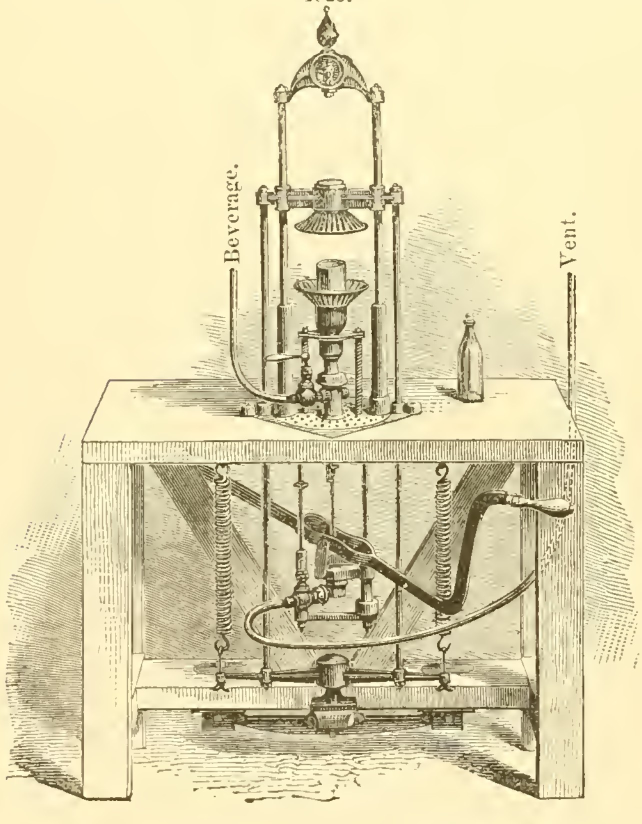
full charge of sulphuric acid and carbonate, as the highest pressure that can be thus developed in the generator does not exceed 1,000 lbs. to the square inch. The best iron generators are made to resist a pressure of 500 lbs. Copper does not answer so well for high-pressure generators, as it is weakened by the heat of the chemical action in the generator during the operation. The best generators are protected from bursting by undue pressure by a safety-cap containing a duplex disk which will sustain a given amount of pressure. If the pressure in the generator exceeds this amount, the disk is ruptured and the pressure escapes. Generators are made of different sizes to carbonate from 500 to 600 gallons of liquid at one operation.

Fig. 1917 represents the Matthews portable steel fountain for containing and transporting carbonated beverages. It consists of an interior fountain of pure sheet-tin, inclosed in an exterior case of sheet-steel of great strength and elasticity. The opening for the stop-cock in the fountain is strengthened by steel washers or rings. The flange of the cock beds down on the bung surmounting the fountain, and is recessed so as to form a matrix to receive a soft metallic or other packing. The lip of the bung of the fountain fits up into the recess and impinges on the packing, which is prevented from spreading by the sides of the recess, thus making a perfect joint. The weight of the steel fountain for holding 10 gallons of beverage is about 40 lbs., while that of the cast-iron fountain is 180 lbs., and of the tin-washed copper fountain 80 lbs. The fountain is filled to about two-thirds its capacity, leaving a space for the gas compressed above the beverage to force the latter out of the fountain. These fountains are also made of wrought-iron and copper.

An improved glass-lined fountain is shown in Fig. 1918, and consists of a glass vessel *a*, encased in a shell of steel, iron, or copper. The gas enters between the glass vessel and its metallic case during the filling of the fountain, and equalizes the pressure inside and outside the glass vessel. Portable fountains are charged by first filling them with the required quantity of liquid to be carbonated, and connecting them with the generator. The carbonic acid gas is let into the fountain at 150 lbs. pressure. The fountain is then shaken to agitate the water and impregnate it with the gas.

One of the principal parts of the continuous system is the beverage-carbonating compressor shown in plan in Fig. 1919, and in elevation and section in Figs. 1920 and 1921. The gas and liquid enter the twin cocks where marked "Gas" and "Water." By the upward stroke of the reciprocating cylinder *D*, they are forced through the valve *L* and passages up and into the receiver *E*, as indicated by the arrows. The reciprocating action of the cylinder and its passages works the agitator *F* with a churning motion. The agitator has one or more volutes to catch and distribute the gas in the water, and to agitate the latter within the receiver. *S* is the safety-valve. The pressure used rarely exceeds 200 lbs. to the square inch. In this machine the feed and the agitator are operated through the base or lower portion of the receiver, and the discharge- or feed-pipe passes from the pump into the receiver and imparts to it a reciprocating action by or with the pump, so that the pressure of the gas or the liquid in the receiver is made to assist the pump in its discharging or feeding stroke to the receiver, by acting on the exposed end of the discharge- or feed-pipe. All the parts exposed to the beverage are encased with pure block-tin, and the agitator-shaft is jacketed with pure silver. All tin-washed surfaces are avoided as not durable.

1923.




In bottling carbonated beverages the Matthews internal gravitating stopper, Fig. 1922, is largely used as a substitute for corks. This stopper consists of a glass stem with a rubber cap. The stopper is forced into the bottle before filling, and can be used repeatedly to close the bottle. The pressure of the carbonated liquid presses the rubber cap against the neck of the bottle; the more pressure the tighter the bottle is closed.

A bottling machine, shown in Fig. 1923, is required to fill bottles closed with this stopper. The bottle is placed neck downward in the socket of the machine, and secured by depressing the foot-lever. By raising the hand-lever a vent-tube is elevated in the bottle. A valve operated by the hand admits the beverage, the air escaping by the vent-valve. As soon as the bottle is filled, the supply-cock is closed and the hand-lever is depressed, withdrawing the vent-tube from the bottle and allowing the stopper to fall into its place in the neck of the bottle, which is then released by elevating the foot-lever, and the operation is completed.

GAS, ILLUMINATING, APPARATUS FOR MANUFACTURE OF. All substances, whether animal, vegetable, or mineral, consisting of carbon, hydrogen, and oxygen, when exposed to a red heat, produce various inflammable elastic fluids, capable of furnishing artificial light. We perceive the evolution of this elastic fluid during the combustion of coal in a common fire. Bituminous coal,

when heated to a certain degree, swells and kindles, and frequently emits remarkably bright streams of flame; and after a certain period these appearances cease, and the coal glows with a red light.

The flame produced from coal, oil, wax, tallow, or other bodies which are composed of carbon and hydrogen, proceeds from the production of carburetted hydrogen gas, evolved from the combustible body when in an ignited state. If coal, instead of being burnt in the way now stated, is submitted to a temperature of ignition in close vessels, all its immediate constituent parts may be collected. The bituminous part is distilled over, in the form of coal-tar, etc., and a large quantity of an aqueous fluid is disengaged at the same time, mixed with a portion of essential oil and various ammoniacal salts. Large quantities of carburetted hydrogen, carbonic oxide, carbonic acid, and sulphuretted hydrogen also make their appearance, together with small quantities of cyanogen, nitrogen, and free hydrogen; and the fixed base of the coal alone remains behind in the distillatory apparatus, in the form of a carbonaceous substance called *coke.* An analysis of coal is thus effected by the process of destructive distillation. The principal products obtained, and their several uses, may be represented as follows:

- COAL.
  - Gas, illuminating, etc.
  - Tar
    - Oils, 30 per cent.
      - Naphtha.
        - Benzole.. { Benzol, Toluol } Used to make aniline.
        - Naphtha—used for varnish.
        - Xylole—used for small-pox remedy.
      - Dead oil.
        - { Carbolic acid, Cresylic acid } Used for disinfectants.
        - Naphthaline—dyes, etc.
        - Anthracene, ½ per cent. Used to make alizarine.
        - Chrysene—no use as yet.
    - Pitch, 70 per cent.
      - Used for roofing and pavements.
      - Anthracene, 2 per cent.
  - Ammonia water
  - Coke, for fuel

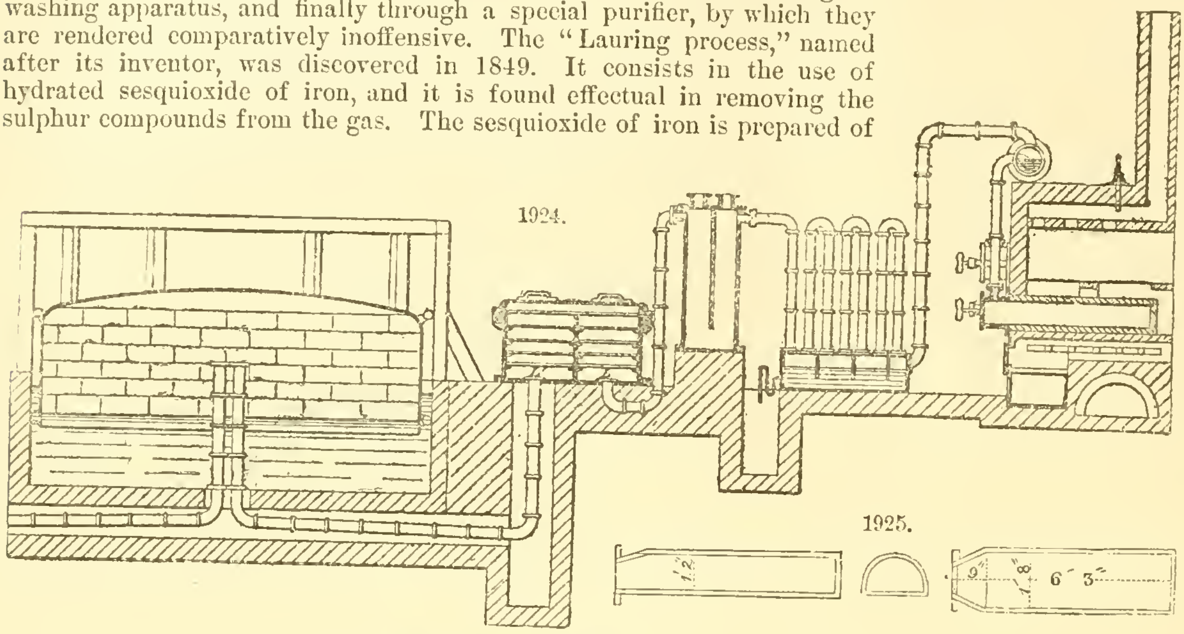
For the manufacture of gas, a coking bituminous coal is greatly preferred, for the reason that it exists in great abundance, and that a compact porous coke remains after it has undergone fusion, which can always be sold at a fair price.

The manufacture of coal-gas consists of three distinct operations: Distillation, condensation, and purification. Distillation is carried on in retorts, which are long, horizontal, semi-cylindrical, D-shaped vessels of cast-iron, or more generally of clay. These consist of two parts, the body and the mouth-piece. The temperature to which the retorts are heated before the coal is introduced varies. For iron retorts, a temperature from 1470° to 1830° F., called a dull cherry-red to a clear cherry-red heat, is generally adopted. For clay retorts, a deep orange (2010° F.) to a clear orange (2190° F.), or even white heat (2370° F.), is employed, the coal itself being exposed, when introduced in either case, to a dull cherry-red heat of 1500° to 1600° F. The temperature to which the coal is raised, and the length of time it is exposed to heat, are matters of considerable importance. Experience has demonstrated that it is better to interrupt the process about four hours after the charge is introduced; for while, at first, condensible vapors rich in carbon are given off, which when passing out are decomposed, yielding fixed gases possessing high illuminating power, yet if the operation is allowed to continue too long, little but hydrogen is given off, and this is apt to be mixed with bisulphide of carbon, a very bad impurity. It is also necessary that the gas be removed as soon as possible. It is therefore drawn up a conduit, called the "ascension-pipe," which is placed near the mouth-piece, and from thence passes to the hydraulic main. An exhauster is employed to remove the gas from the retorts, and more particularly to force the gas ahead through the condenser, washer, and purifiers into the holder, and thus enable more gas to follow from the retort. In the hydraulic main a portion of the tarry matters becomes deposited. The hydraulic main is a large horizontal tube which extends the whole length of the retort-house, receiving the dip of pipes of successive benches of retorts in its passage. This tube is half filled with tar and ammoniacal water, which is always maintained at a constant level by an overflow to the tar-well, and enables it to act as a contrivance for sealing the pipes, so that gas will not escape during the drawing and charging of retorts. From the hydraulic main the gas passes to the condenser, which consists of a series of iron tubes, which are usually placed in cisterns of cold water or exposed to the air; by this means the gas is cooled, and the tarry and aqueous matters held in suspension are deposited. By a simple contrivance the tar and ammoniacal liquor which separate in the condenser are made to flow into different wells. The gas passes into a washer, and then into a scrubber, or into the scrubber direct at works where washers are not used. By this passage of the gas through the washer, where it is made to bubble through water, and by its exposure to wet surfaces of large extent in the scrubber, the ammonia, last traces of tar, and considerable of the sulphuretted hydrogen and sulphur compounds are removed. None but a mere trace of ammonia remains after the passage of the gas through the scrubber.

PURIFICATION.—Four methods for the purification of gas are used, namely: the "wet-lime process," the "dry-lime process," the "Lauring process," and the "iron-ore process." By the first, the gas is made to pass through milk of lime, which is very effectual in separating the sulphur compounds and carbonic acid; but this process has been in great measure abandoned, for the reason that there is no use for the saturated milk of lime, called "blue billy," which is very foul, and, not oxidizing rapidly, is useless as a fertilizer. In the "dry-lime process," which has superseded the foregoing, dry or slightly moist hydrate of lime is placed on trays in iron boxes, through which the gas is made to pass. This process is equally effectual in separating the sulphur compounds and carbonic acid. When this saturated lime is exposed to the air, it is rapidly oxidized, becoming heated and giving off the same odor as the wet-lime process, which is very offensive, and was the source of considerable com-

plaint by every person who dwelt in the vicinity of gas-works until a system for deodorizing the foul lime was invented, which effects its oxidation in such a manner that the offensive gases evolved are not permitted to pass into the atmosphere, but are conducted through a washing apparatus, and finally through a special purifier, by which they are rendered comparatively inoffensive. The "Lauring process," named after its inventor, was discovered in 1849. It consists in the use of hydrated sesquioxide of iron, and it is found effectual in removing the sulphur compounds from the gas. The sesquioxide of iron is prepared of

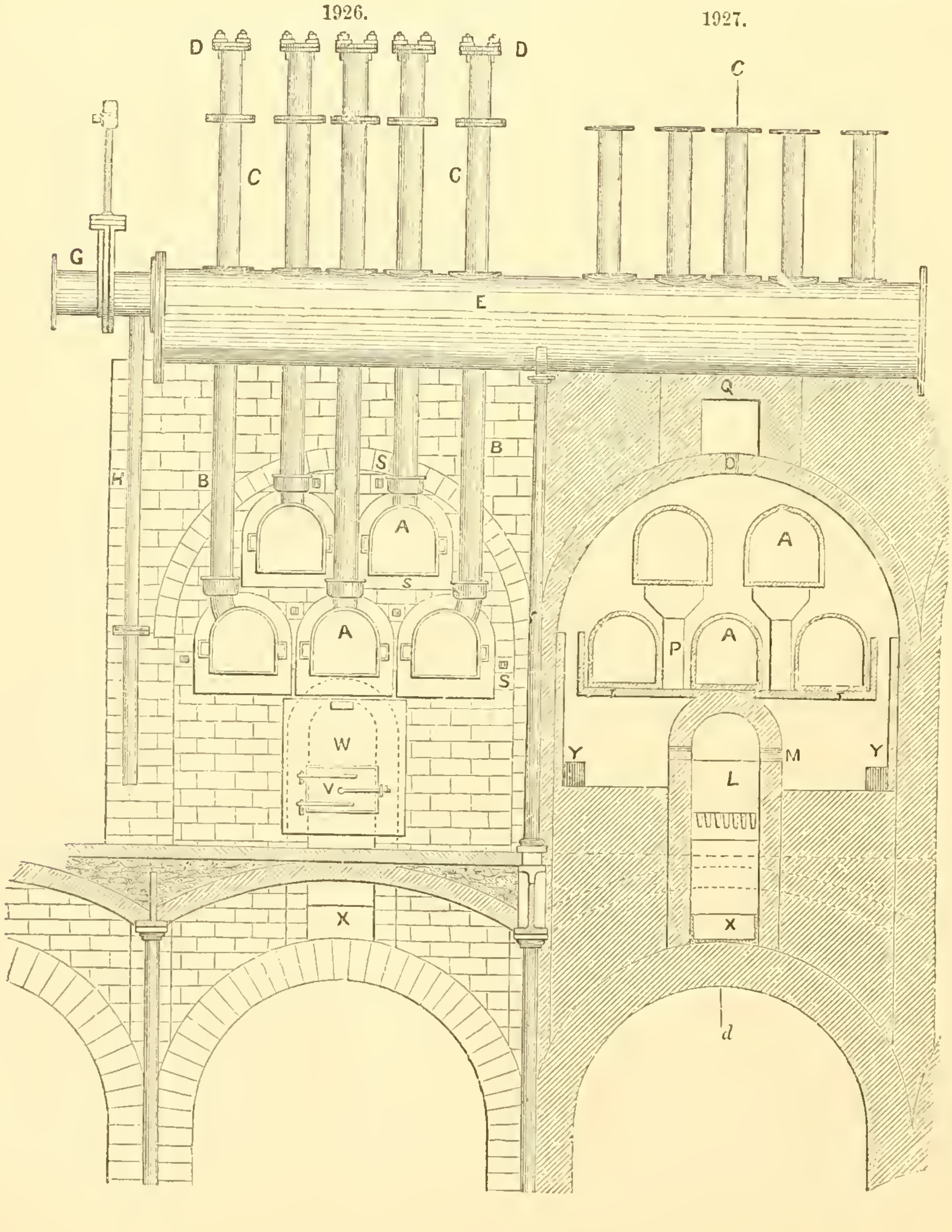
1924.



1925.



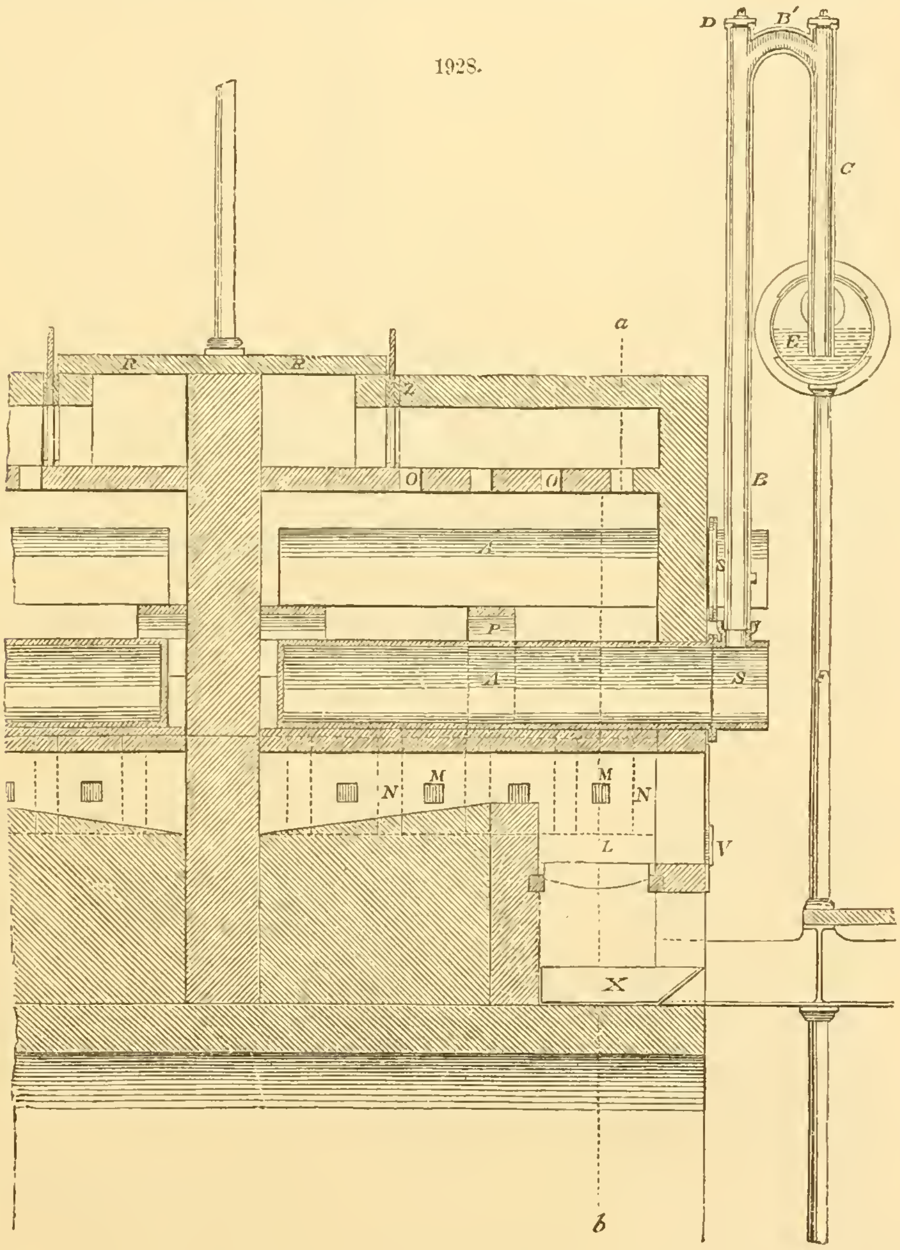
1926. 1927.



suitable quality by mixing copperas with slaked lime and sawdust, and exposing the mixture to the air, so as to oxidize the protoxide of iron to the sesquioxide. The resulting mixture contains hydrated sesquioxide of iron, sulphate of lime (hydrate of lime), and saw-dust. When this mixture has been used, it can be exposed to the air, and will not give off any offensive odors. The air, acting upon the sulphide of iron formed in the purifier, liberates the sulphur, and sesquioxide of iron is again produced. The mixture can therefore be repeatedly used, until it becomes so impregnated with liberated sulphur as to prevent its acting rapidly on the gas. It has been used for periods of a year at a time. When saturated, the material can be employed for the manufacture of sulphuric acid, as it then contains from 40 to 60 per cent. of sulphur.

The iron-ore process involves the use of the natural sesquioxide of iron or "bog-iron ore." This material may also be used over and over again, and when exposed to the air does not evolve offensive odors. It has been largely adopted in preference to Lauring's mixture, as experience has shown that the sulphate and hydrate of lime present in the latter do not take any appreciable part in the purification. An improvement on this process was made by Messrs. St. John and Cartwright, and has been in use nearly seven years at the New York Gas-Works, giving entire satisfaction. As the bog-iron ores of this neighborhood are not sufficiently pulverulent, St. John and Cartwright add to the ore a quantity of iron borings or turnings, which they convert into artificial hydrated sesquioxide of iron by moistening the whole with ammoniacal liquor and exposing the same to the air. Charcoal is then added to the mass, which consists of natural and artificial oxide. Before placing the mixture

1928.



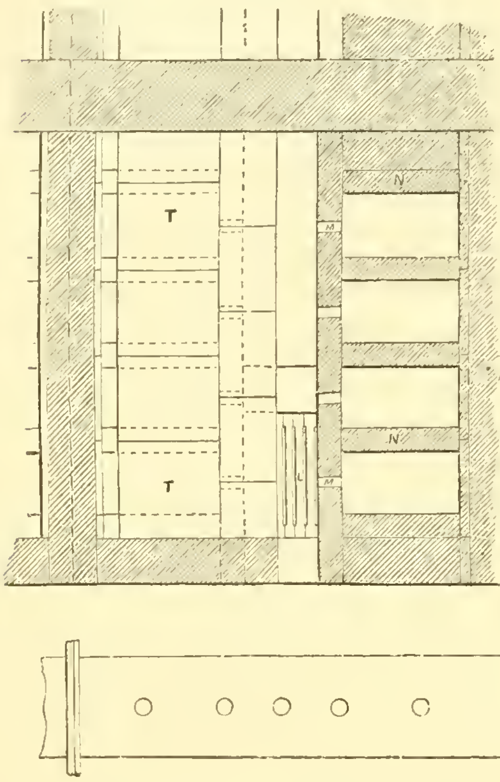

in the purifier, it is moistened with ammoniacal liquor. Several varieties of the natural sesquioxide of iron are in use in different parts of Europe.

Apparatus.—Fig. 1924 shows the general arrangement and interrelation of the retorts, hydraulic main, condenser, washer, purifier, and holder or gasometer.

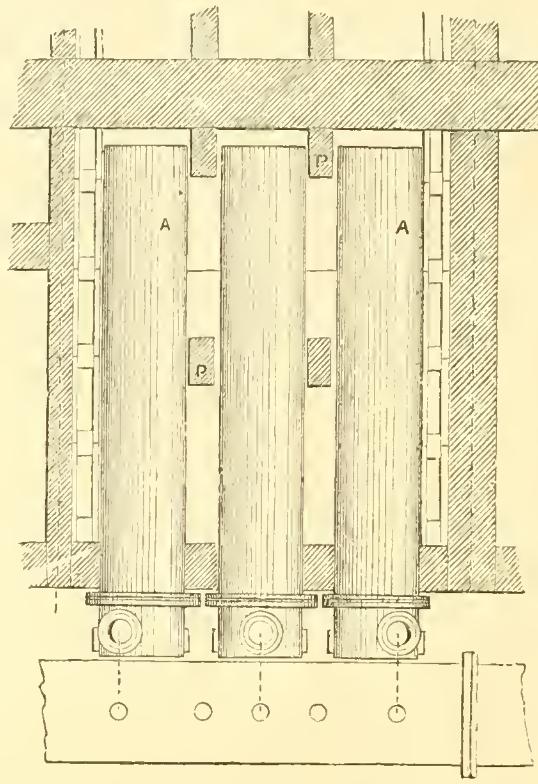
Retorts.—The proper mode of constructing retorts in which coal is distilled, and the art of applying them, form objects of primary importance in every gas-light establishment. The forms of the retorts used are various. Fig. 1925 represents sections of a retort of cast-iron, commonly known as

the "D" retort. As clay retorts have been found by experience to be much better than iron retorts, the latter are going rapidly out of use. Fire-clay retorts admit of being heated to a higher temperature than iron retorts, and they are capable of holding their heat much longer. The dimensions of retorts that are now in use vary considerably. Single retorts, however, should be 21 by 14 inches

1929.

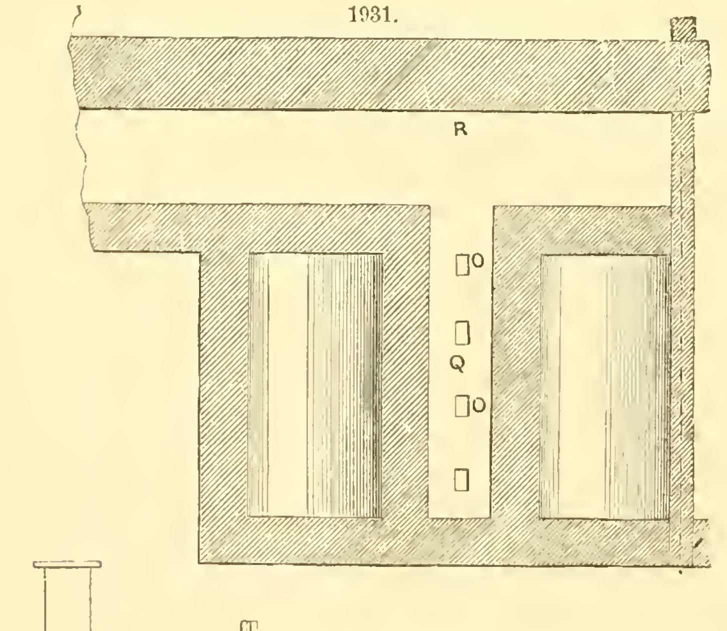



1930.




and 8 or 8½ feet long internally, so as to be capable of receiving large charges, and of being easily drawn—two important considerations, as affecting economy of labor in carbonization. Retorts which are called "through retorts" ought to have about the same internal diameter, and a length of from 18 to 20 feet. The through retorts are open at both ends and closed by mouth-pieces; while the single retort is closed at one end and open at the other, capable of being closed also by a mouth-piece.

1931.

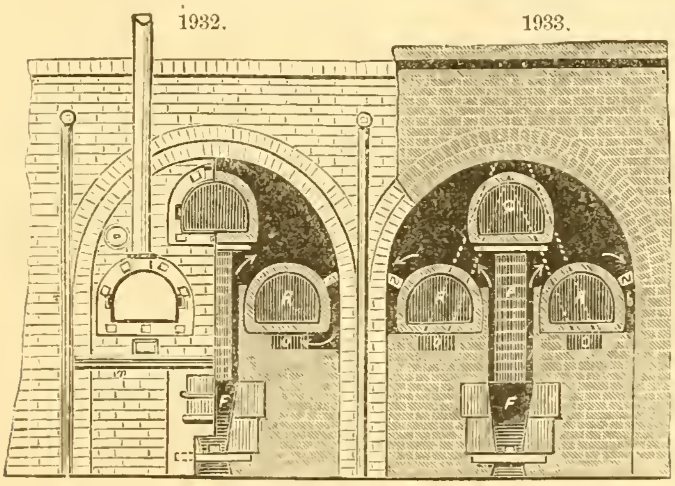



*Mode of setting Retorts.*—In Figs. 1926 to 1931 is represented the old method of setting a bench of five retorts. Fig. 1926 is a front elevation, Fig. 1927 a transverse section through *a b* in Fig. 1928, and Fig. 1928 a longitudinal section through *c d* in Fig. 1927. Fig. 1929 is a plan showing the furnace and side openings below the fire-tiles on which the lower retorts rest, and the bedding of the lower retorts. Fig. 1930 is a plan over the three lower retorts, the two upper retorts being removed. Fig. 1931 is a plan over the oven-arch, showing the flues, etc.

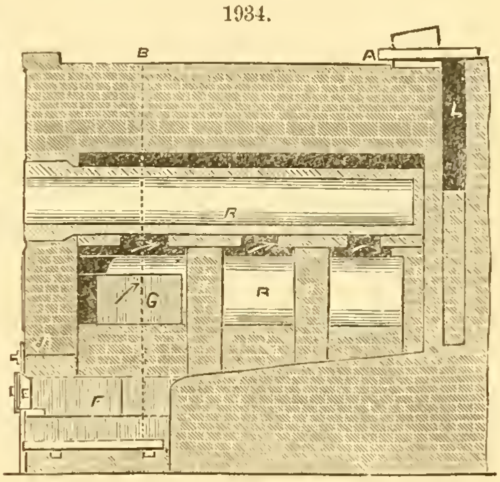
*A A* are retorts of the kind called D. *S* is the mouth-piece, 10 inches long, with a socket cast on the top to receive the stand-pipe. Each socket has a neck, as shown in the figure, the length of which is from 4 to 5 inches. *B* is the "stand-pipe," through which the gas as it is generated passes from the retort. *B′* is the "bridge-piece" connecting the stand- and dip-pipes. *C* is the "dip-pipe." *D D* are the bonnets, to be removed when the pipes require clearing, jointed by putty and pasteboard. *E* is the hydraulic main. *F* is a light hollow cast-iron pillar, supporting the hydraulic main in the centre of each length; it is based upon the cast-iron girder which supports the firing-floor. *G* is the pipe through which the gas makes its exit from the hydraulic main to the condensers, furnished with slide-valves to disconnect the mains at each side of the house, when at any time it is

found necessary to repair or clear them. *H* is a small pipe for conveying the surplus tar formed in the hydraulic main to the tar-well. *L* is the furnace for heating the retorts; its breadth is 14 inches, the length of the fire-bars 24 inches. *M M* are side openings, 3 inches square, left in the brick-work, through which the heat of the furnace passes. *N N* are 4½-inch walls, built of fire-bricks, one between each of the openings *m*; they serve to support the fire-tiles *T*, on which the outside lower retorts rest. The direction of the flues is shown by arrows. *P P* are fire-bricks, placed on end, and a fire-lump upon which the two upper retorts rest. *O O* are openings 3 by 4½ inches in the crown of the main arch communicating with the branch flame. *Q* is the branch flue, one being built over the centre of each bench of retorts. *R* is the main flue, running the entire length of the benches, and connecting with the chimney, into which all the branches lead. Between this main flue and each branch are dampers to regulate the draught through the furnaces. *S S* are cast-iron plugs, covering sight-holes through which the heat of the retorts is seen and judged of. *V* is the furnace-door, protected by a fire-lump inside. *W* is a cast-iron plate, 1½ inch thick, on which the fire-door is hinged, serving also to protect the face of the brickwork which it covers. In the centre, and about 6 inches above the fire-door, a square opening is cast for the admission of an iron spout when it is required to burn tar. *X* is a pan at the bottom of the ash-pit, for evaporating ammoniacal liquor, and the offensive liquid products which could not be disposed of in olden times. *Y Y* are openings left in the wall *N*, by which the carbon deposited from the furnace is cleared away. The oven represented in Figs. 1926 and 1927 is a good arrangement. The heat from the furnace passes through the square openings *M* at each side, and is thus equally divided along the whole length of the retorts; from between the walls *N* it rises between the fire-tiles at the outer sides of the lower retorts. The flame is not suffered to impinge upon any part, but is equally distributed throughout the oven, and consequently the retorts work and "burn out" evenly. The lower retorts, which would otherwise be exposed to a more direct heat, are carefully guarded by fire-tiles, which at the same time prevent the bottoms from bulging. The openings *O* at the top of the main arch act more in the manner of

1932. 1933.



1934.

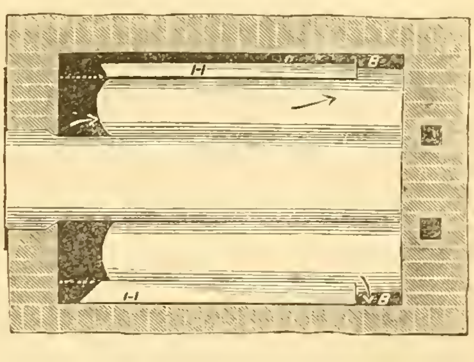


safety-valves than flues, serving to regulate the final exit of the heated air, and, being distributed along the outer length, they do not draw the flame to one part. The whole interior of the oven, as well as those parts in contact with the flame, must be constructed of fire-bricks. The main arch, 6 feet in span and half a brick in thickness, is formed of bricks moulded on purpose to suit the curve, the joint being kept as close as possible. As this arch is permanent, much care should be taken in its formation.

A bench of iron retorts arranged on this plan, if well and regularly used, ought to last 12 to 14 or even 15 months, and should never be allowed to become cold. The first portion of oxide which forms upon the surface, when allowed to cool, cracks and falls off, leaving a new surface to be acted upon the next time it is heated.

Figs. 1932 to 1935 represent a method for setting a bench of three retorts, which has proved very valuable, each retort having an internal measure of 15 × 12 inches. Fig. 1932 represents the bed, one half in elevation, the other half having the front wall removed, in order to show the entrance to flues *O O*, Fig 1933, which extend underneath each retort, and communicate with the vertical flues, shown in dotted lines in Figs. 1933 and 1934, and partly in section in Fig. 1934, and marked *L*, and in Fig. 1935 in plan. The frame of the furnace-door is secured by a horizontal bar *P*, and bolted at both ends to the buckstaves *T T*, this method being sometimes adopted instead of bolts imbedded in the brick-work. *F* is the furnace, the sides being formed of large blocks, which, as already stated, are more durable than bricks, the quality of material in both cases being alike. For carrying repairs into execution, the furnace being "let down" and cold, the door and frame are removed, and the brickwork of the front wall is cut away.

1935.

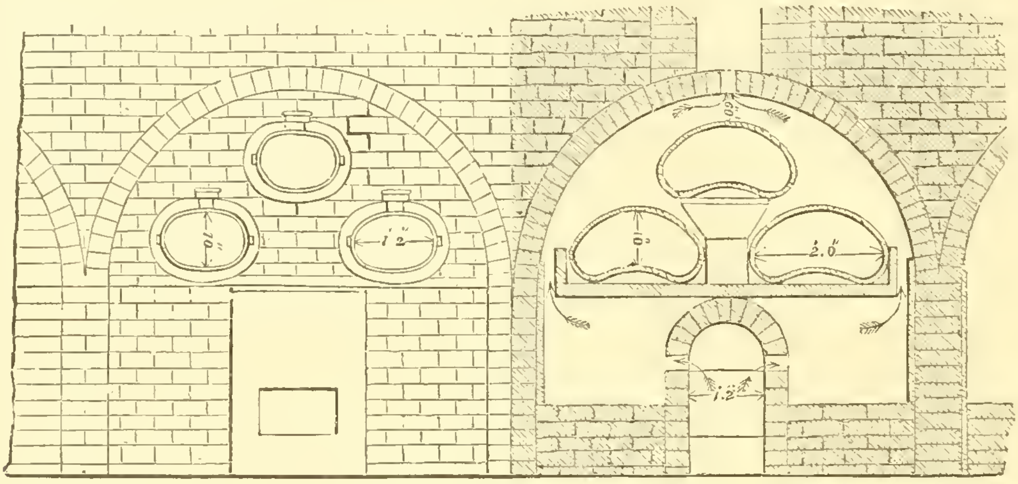


In Fig. 1934, *G* are guard-tiles, to protect the lower retorts from the direct action of the fire at these points; *H* is a course of tiles, shown in plan in Fig. 1935, placed so as to form a flue, *B*, from

the back of the retort to the front. There is only one fire-bar of 2-inch square wrought-iron, the two bearers being of the same material. The fire-bar projects to the level of the front of the wall, a space existing between the former and the frame of the furnace-door, and through this space, as well as underneath the furnace, passes the supply of air to the fuel. In the same figure is represented one of the sight-boxes, as well as a clearing-out box for the flue.

Fig. 1934 is a longitudinal section direct through the centre of the bed, showing the arch *J*, immediately over the furnace-door, the front wall being 14 inches thick; also the fire-brick lintel *E*, with

1936. 1937.



the dead-plate attached to the door-frame, which facilitates clinkering. The top retort is supported by the piers *P P* and their respective slabs. *L* is the flue, at the junction of the two vertical flues.

Fig. 1933 is a section through the line *B*, all the letters of reference corresponding. The vertical flues, shown in dotted lines, connect the flues *O* with the main flue, the damper closing the communication between the beds and the main flue. The latter, for want of space, is omitted.

Fig. 1935 is a plan of the setting, the arch being removed at the points *A A*, showing the two vertical flues *L L*, also the entrances to the two flues *B*, formed by the tiles *H* (*N* in Fig. 1933) which convey the caloric along the sides of the lower retorts into the flues *O*, hence to the vertical flues, as indicated by the arrows.

*Ear-shaped Retorts.*—Fig. 1936 is a front elevation of a bench containing three retorts.

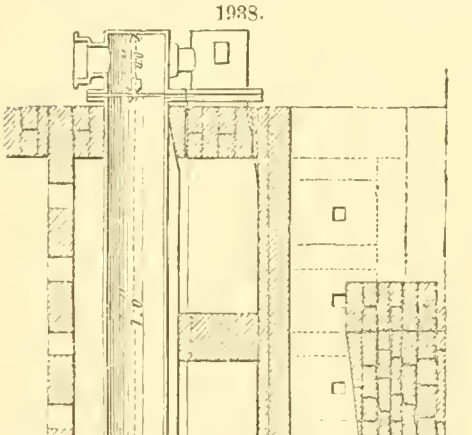
Fig. 1937 is a section taken transversely

Fig. 1938 is a longitudinal section through the centre of the arch.

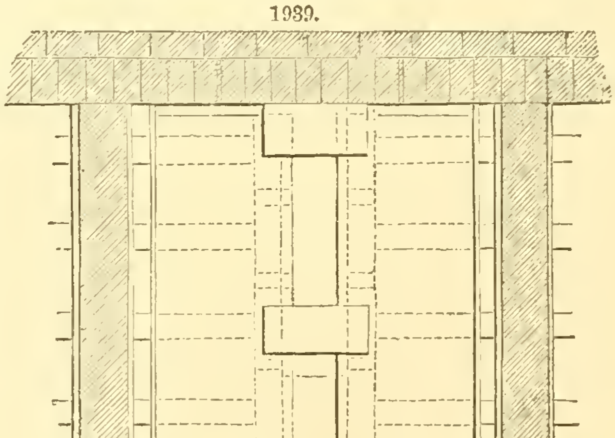
Fig. 1939 is a plan of Fig. 1938.

The method adopted for setting retorts at the New York Gas-Works is illustrated in Figs. 1940 to 1943. The retorts used are neither D-shaped nor oval, but are made up of the two forms, similar to

1938.



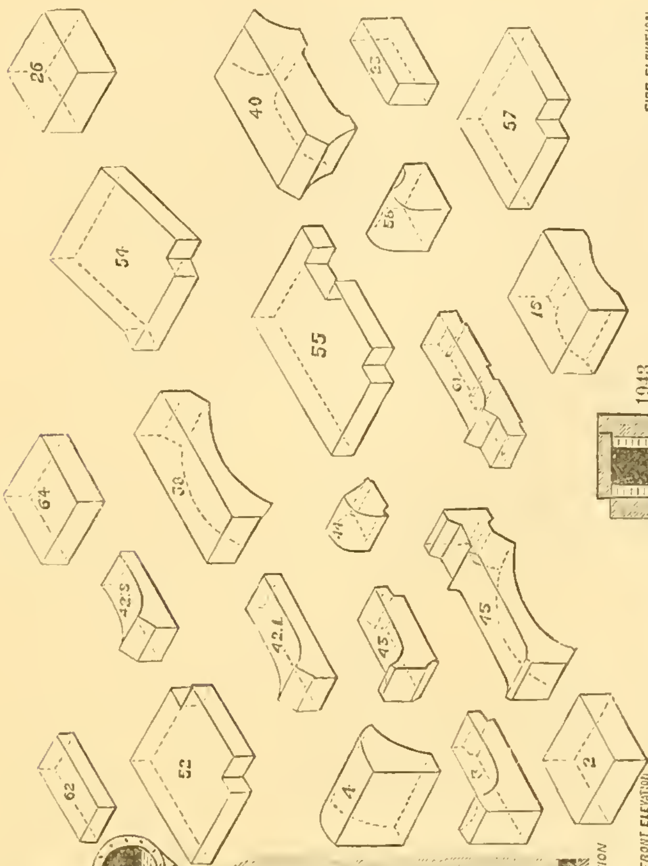
1939.



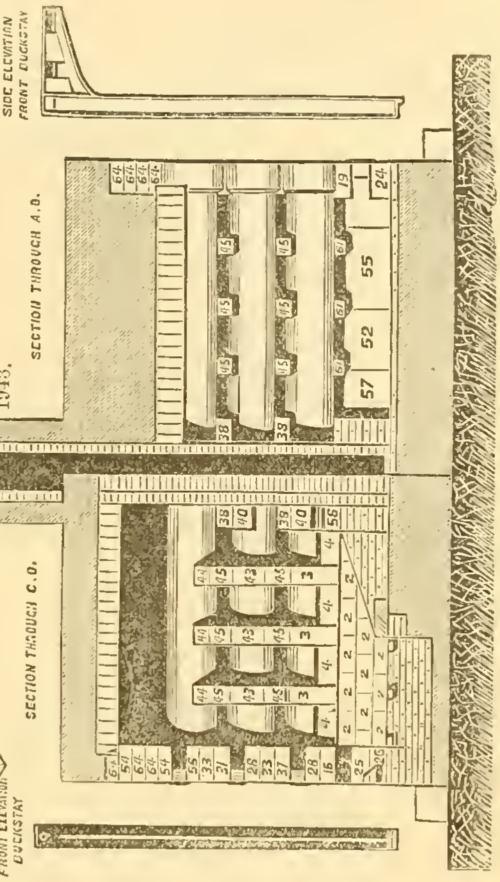
the ear-shaped retorts just mentioned. "Their dimensions are 24 by 13 inches, and 8 feet long, set six in an oven, and almost entirely with tiles and quarries moulded to fit into their respective places in the setting. The heat ascends from the furnace between the two vertical rows of retorts, passes over the top, down the outside to the top of the oven, through the horizontal flues nearest to the furnace on both sides, and thence by way of the vertical shafts into the main flue on the bench. The average make per mouth-piece is said to be 7,500 cubic feet of gas per day, and the quantity produced per ton over 10,000 cubic feet, a percentage of cannel coal being used."

*Brunton's Retort.*—Fig. 1944 represents a front view of a bench of four retorts, upon Mr. Brunton's principle. *A A* are the retort-mouths, the lids of which are fitted with stuffing-boxes, for the reason to be presently described, and permanently jointed in their places with iron cement. *B B* are hoppers, capable of holding from 20 to 28 lbs. of coal, which, when an air-tight slide-valve *C* is drawn

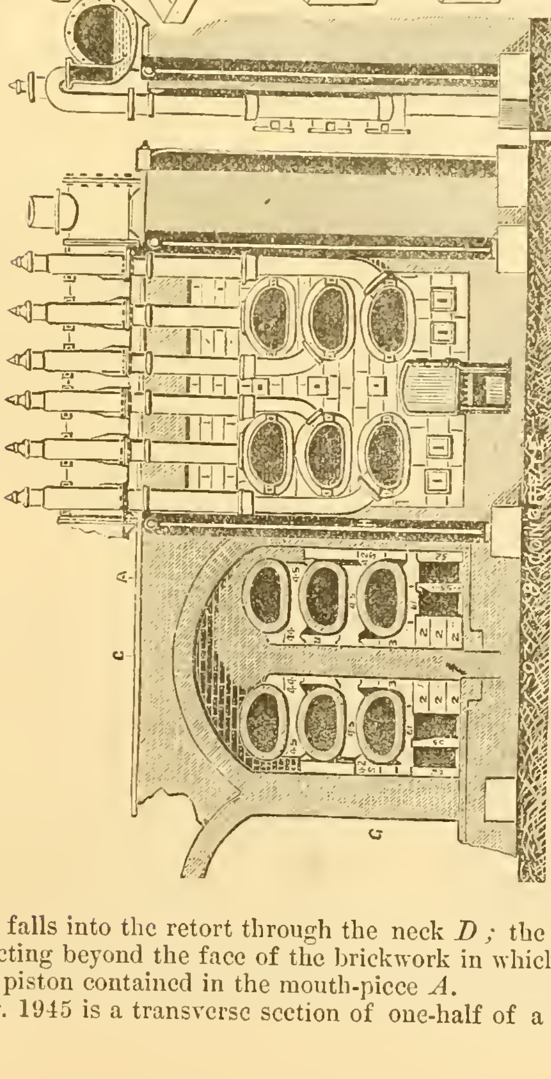
1941.



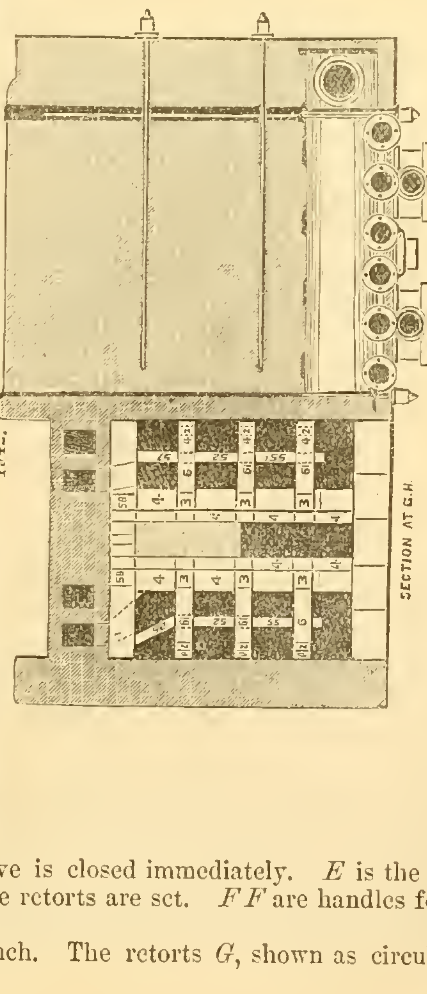
1943.




1940.




1942.



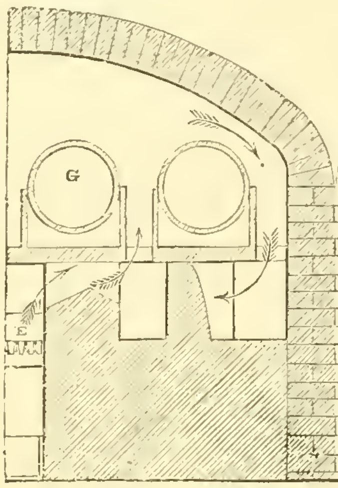

back, falls into the retort through the neck *D*; the valve is closed immediately. *E* is the furnace, projecting beyond the face of the brickwork in which the retorts are set. *F F* are handles for working a piston contained in the mouth-piece *A*.

Fig. 1945 is a transverse section of one-half of a bench. The retorts *G*, shown as circular, may

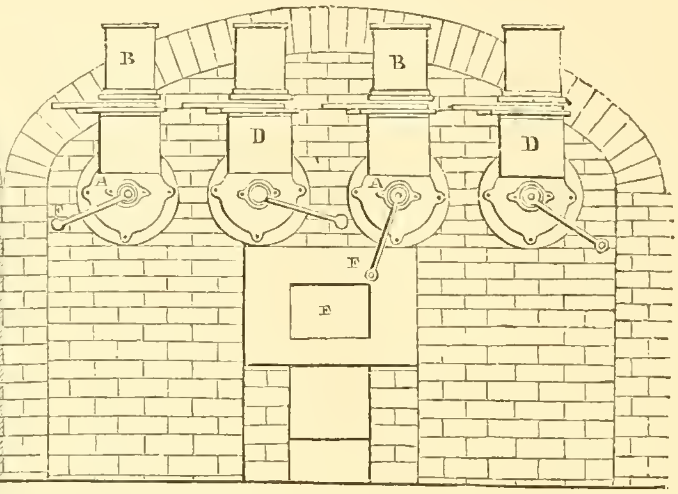
be varied in form if thought necessary. We believe the patentee gives the preference to those of a D-shape. *E* is the furnace; the direction of the flues is shown by arrows.

Fig. 1946 is a longitudinal section through the centre of the furnace. *H* is a short pipe, open to

1945.




1944.




the interior of the retort, sealed at the lower end by dipping into water, through which, after a charge is thrown into the retort from the hopper *B*, a portion of coke is expelled, by advancing the piston contained in the mouth-piece. *I* is the pipe by which the gas, as it is formed, passes to the hydraulic main. *K* is a bonnet, to be taken off at any time when required to examine the interior of the retort.

1946.

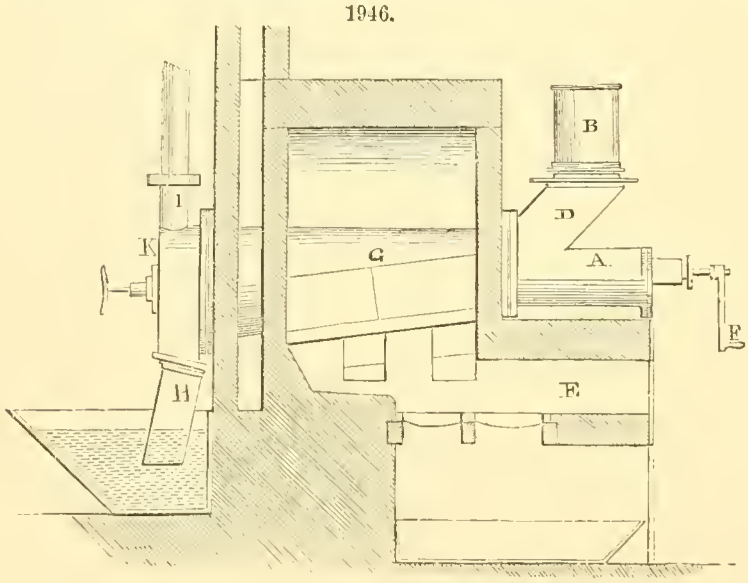
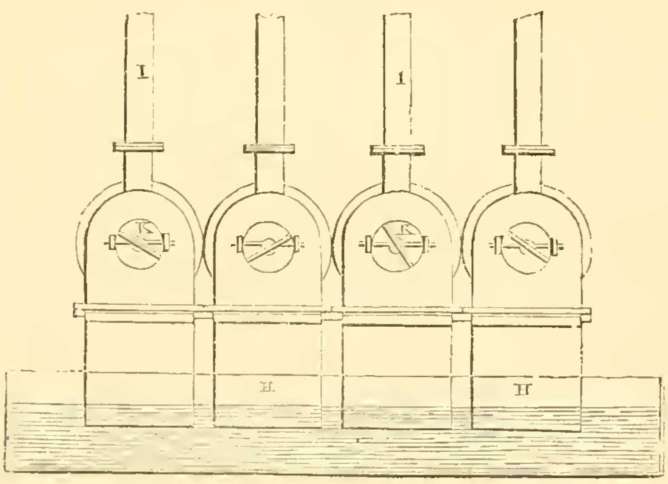



Fig. 1947 is a back view of Fig. 1944.

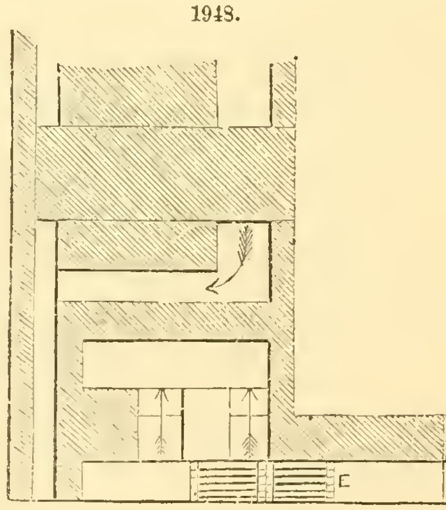
Fig. 1948 is a plan below the retorts. (The same letters refer to corresponding parts in all the figures.)

The annexed diagram, Fig. 1949, will explain the construction of the piston before alluded to. *a* is the piston, drawn back in the proper position to receive a charge, which, when the slide-valve is opened, will fall into the space *b*, and be propelled forward into the heated part of the retort by turning the screw *c*, which works in a nut *d* on the back of the piston. *e* is a collar upon the shaft of the screw, working between the bottom of the stuffing-box and a washer held in its place by four pins. The stuffing-box is made tight in the usual way, by screwing the gland *f* against a gasket. *g* is a shield loosely

1947.




1948.




attached to the front of the piston, to prevent the accumulation of small coal-dust in the mouth of the retort. When the charge is thrust forward, the piston is turned back directly into the mouth, to preserve it from the action of the heat. That part of the retort adjacent to the flues only is

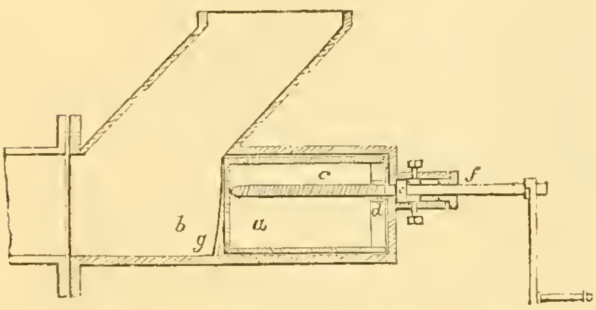
heated, and is consequently the only part liable to much wear and tear. The only part requiring renewal is that of the retort situated between the outer walls of the bench, and weighing about 9 or 10 cwt. The fuel required to carbonize the coal is about 25 per cent. in coal on the quantity distilled.

*Reciprocating Retort.*—It has been stated that the first portion of vapor produced by coal when undergoing destructive distillation in ordinary retorts will, when converted into gas, form that of the most brilliant quality; and it is to effect this that the following arrangements have been patented.

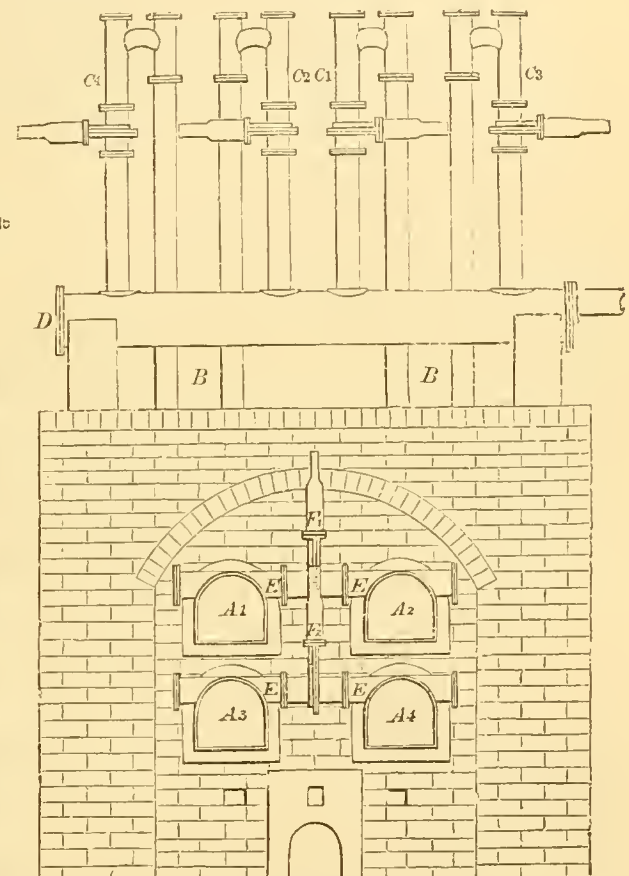
Fig. 1950 is a back elevation of two pairs of retorts. $A^1$ $A^2$ $A^3$ $A^4$ are the retorts; $B$ $B$, the stand-pipes; $C^1$ $C^2$ $C^3$ $C^4$, slide-valves for opening and shutting off the communication between the retorts and hydraulic main; $D$ is the hydraulic main. The front elevation differs but little from it.

Fig. 1951 is a plan of the lower pair of retorts. The operation is as follows: Supposing the entire bench to be at the requisite heat for decomposing the coal, and that they are working six hours' charges, the lids of the retorts $A^1$ and $A^3$ are removed, and by means of scoops (each half the length of the retort) the coal is introduced at both ends, and the lids immediately secured in their places; the slides $F^1$ and $F^2$ are opened, and $C^1$ and $C^3$ closed. The bituminous vapors that rise

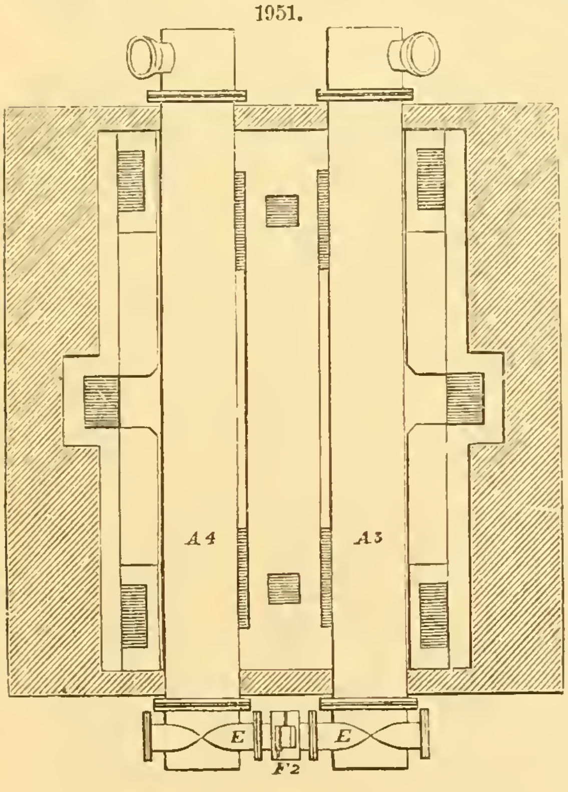
1949.




1950.




1951.




first will pass through the pipes $E$ $E$, and thence through the entire length of the hot retorts $A^2$ and $A^4$, and be converted into gas, which will pass to the hydraulic main by the stand-pipes on which the slide-valves $C^2$ and $C^4$ are fixed, and which remain open. When the distillation has gone on for half the duration of the charge—viz., three hours—the valves $C^1$ and $C^3$ are opened, $F^1$ and $F^2$ shut, and the gas evolved from the retorts $A^1$ and $A^3$ passes through the stand-pipes attached to them. The retorts $A^2$ and $A^4$ are now charged, the mouths closed, the valves $F^1$ and $F^2$ again opened, and $C^2$ and $C^4$ shut. The operation is now reversed, the first vapors passing through the two first-charged retorts until their charge is expended, when $C^2$ and $C^4$ are opened, $F^1$ and $F^2$ closed, and the charge drawn. They are then immediately recharged, and the operation of opening and closing the valves is repeated.

Retorts on this construction have been worked, and are found to act well, producing gas of average quality and in greater abundance than by the ordinary method. The reason of the gas being only of an average quality is, that the carburetted hydrogen made after the production of bituminous vapor has ceased still passes over the red-hot surface of another retort and deposits some portion of its carbon, the rich gas formed by the conversion of the bituminous vapor only serving to make up the deficiency. If, instead of having only two retorts in a set, the number could be increased to six,

and after the first hour the gas be allowed to pass away on the ordinary plan, both the quantity would be augmented and the quality improved.

*Revolving-Web Retort.*—This retort is arranged so that the coal is acted upon in a thin stratum and converted into gas at once. The chemical advantages of this method are many. All the elements of the coal are liberated nearly at the same time, and unite with one another in such proportions as to form gas of the best illuminating quality, and in greater abundance than when the coal is carbonized in mass. The condensed bituminous vapor which forms tar in the ordinary process is by this nearly all converted into olefiant gas.

1952.

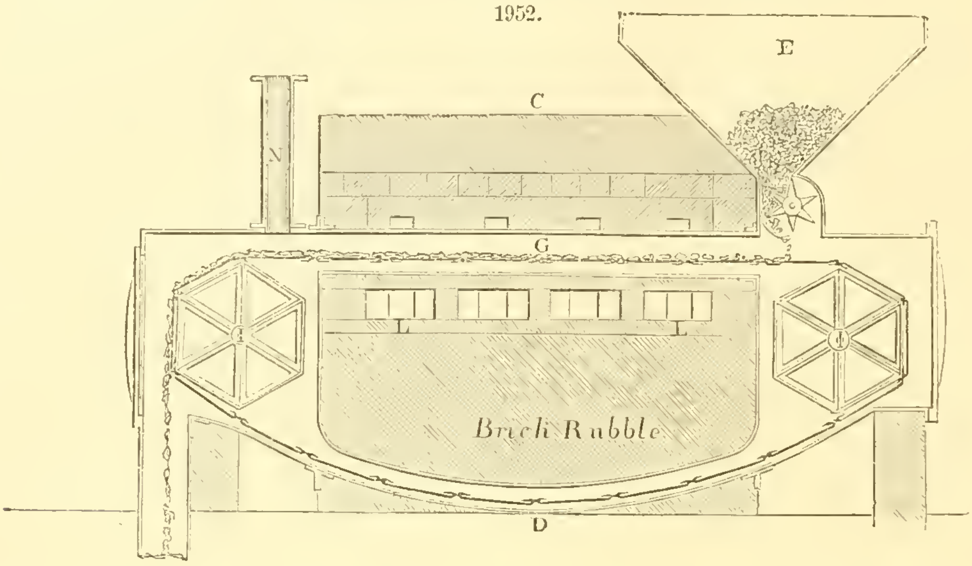
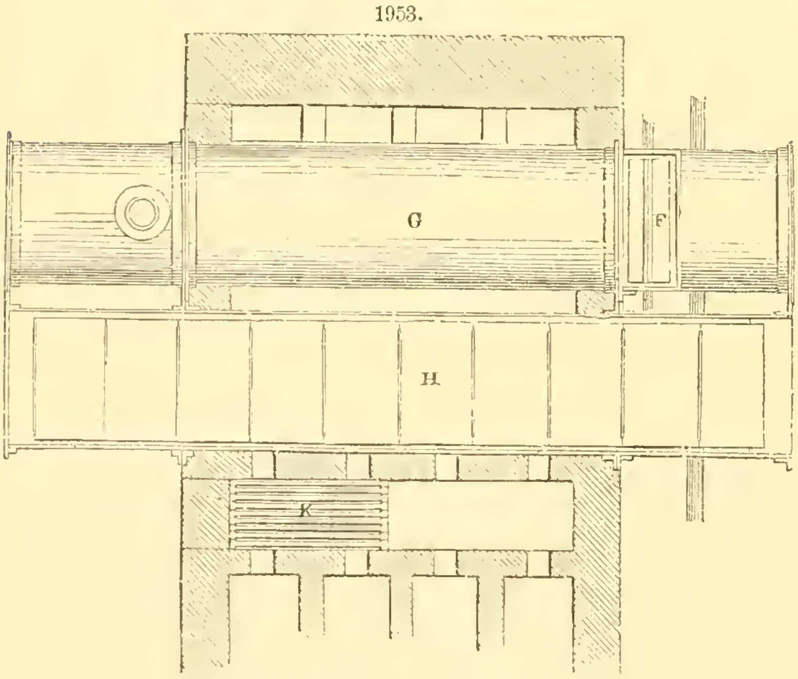


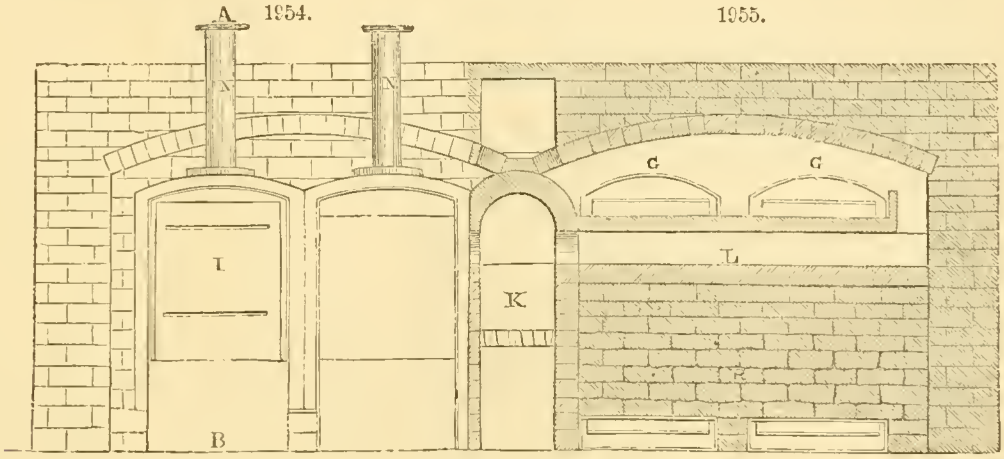

Fig. 1952 is a longitudinal section through *A B* in Fig. 1954. Fig. 1955 is a transverse section through *C D* in Fig. 1952. Fig. 1953, plans of the retort in section, over the top of the retort, the web, and furnace, respectively. The same letters refer to corresponding parts in all the figures. *E* is a hopper containing the coal; *F* is the discharging-disk; *G* is the retort; *H* is a web on to which the coal is discharged by the disk *F; I I* are revolving drums carrying the web *H; K* is the furnace; *L L*, the flues passing under and over the retorts, and finally into the main flue; *M*, the shoot into which the coke falls, the end of which may either dip into water or be furnished with a tight door. The retort itself, and the chamber in which the drums work, are made of wrought-iron boiler-plates, riveted together so as to be quite gas-tight. The only parts subject to wear and tear are the retort adjoining the flues and the web, both of which are heated; the latter, however, never becomes so hot that the shape alters The action of this arrangement is as follows: All the coal must be either ground or beaten small and screened, so that no lumps remain larger than coffee-berries, and a 24 hours' charge must be thrown into the hopper and secured by a luted cover. The discharging-disk, which is 9 inches in diameter, with 6 arms, is made to revolve uniformly with the drum below it, at the rate of 4 revolutions an hour; for this purpose two shafts run the entire length of the retort-beds, on one of which the drums are fixed; on the other are the discharging-disks, connected at one end by a strap. The diameter of the hexagonal drums is so regulated that the coal which falls on the web from the discharging-lip will at one revolution have passed the entire length of the retort. Fifteen minutes is sufficient time to convert the coal so distributed into gas. Each link of the web is 14 inches long and 24 inches broad, having a surface of 336 square inches, upon which the contents of one partition of the disk will be discharged, viz., a little more than 124 cubic inches of coal in a stratum less than three-eighths of an inch thick. Each successive link receives the same quantity, so that, in one entire revolution of the disk and drum, 745 cubic inches of coal (equal to 21 lbs.) are distributed over a heated surface of 2,016 square inches, and converted into gas. By this process 84 lbs. of coal will make 450 cubic feet of gas of the specific gravity .490. It therefore

1953.



follows that in 24 hours 18 cwt. of coal will be discharged by each retort, making 10,800 cubic feet of gas, equal to 12,000 cubic feet per ton. The quantity of gas produced by five D retorts, such as are shown in Fig. 1926, will be about 14,000 cubic feet in 24 hours, of specific gravity .390 or .400; and the quantity produced by four of the revolving-web retorts will be 43,200 cubic feet in 24 hours, of the specific gravity .470 or .490.

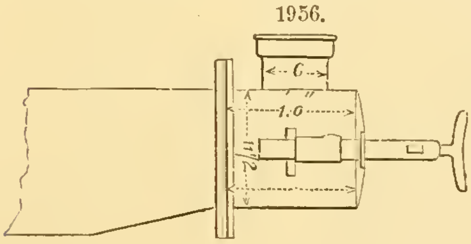
1954. 1955.



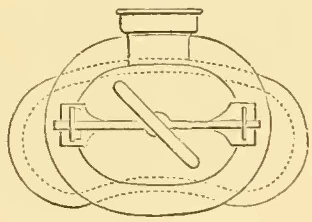

*Mouth-Pieces and Lid of Retorts.*—The old methods adopted for securing the lid in ordinary retorts are represented in Figs. 1956, 1957, and 1958. These figures are views of a mouth-piece on a scale of half an inch to a foot. The mouth-piece was three-quarters of an inch thick, secured to the retort by bolts and a cement joint made between their flanges.

The mouth-piece is always made of cast-iron, even in the fire-clay retorts, and is fastened in the ordinary way by means of iron bolts and cement. A gas-tight joint is obtained by using a mixture of iron filings and gypsum, which is made into a paste with an aqueous solution of sal ammoniac. Fitted to the mouth-piece is a short tube in which the ascension-pipe sets, for carrying off the gases and vapors evolved during distillation. In front of the mouth-piece is fitted a lid of wrought or cast iron. In the ordinary mouth-piece a gas-tight joint is obtained by means of luting, the lid being pressed down tight by means of a screw and cross-bar into the mouth of the retort. One of the

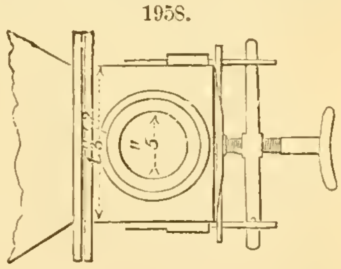
1956.



1957.



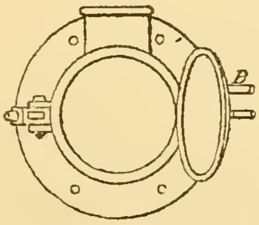
1958.



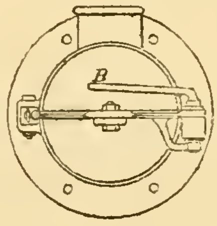
most important improvements made of late is a method by which luting is rendered unnecessary wherever the exhauster is in use. The lid of the mouth-piece is made so true (as also the mouth-piece itself) that the pressure of a lever insures a perfectly gas-tight union. This device, known as the Morton mouth-piece, is shown in Figs. 1959 and 1960. The door is closed by turning the handle *B*, which, acting as an eccentric, presses with sufficient force to produce a gas-tight joint.

*Scoops or Shovels.*—To introduce the coal into the retorts, when a mechanical retort-stoker is not used, a "scoop" is employed, in preference to a shovel. The scoop is a semi-cylinder made of thin plate-iron, 6 feet 6 inches long and 12 inches in diameter, with a cross-handle at one end, represented in Fig. 1961. The charge for the retort is placed in this; one man takes the cross-handle, and two others at the opposite end lift it with its contents up to the retort; it is then pushed forward, quite to the bottom, turned round, and withdrawn immediately, and the coal left in

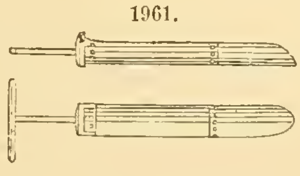
1959.



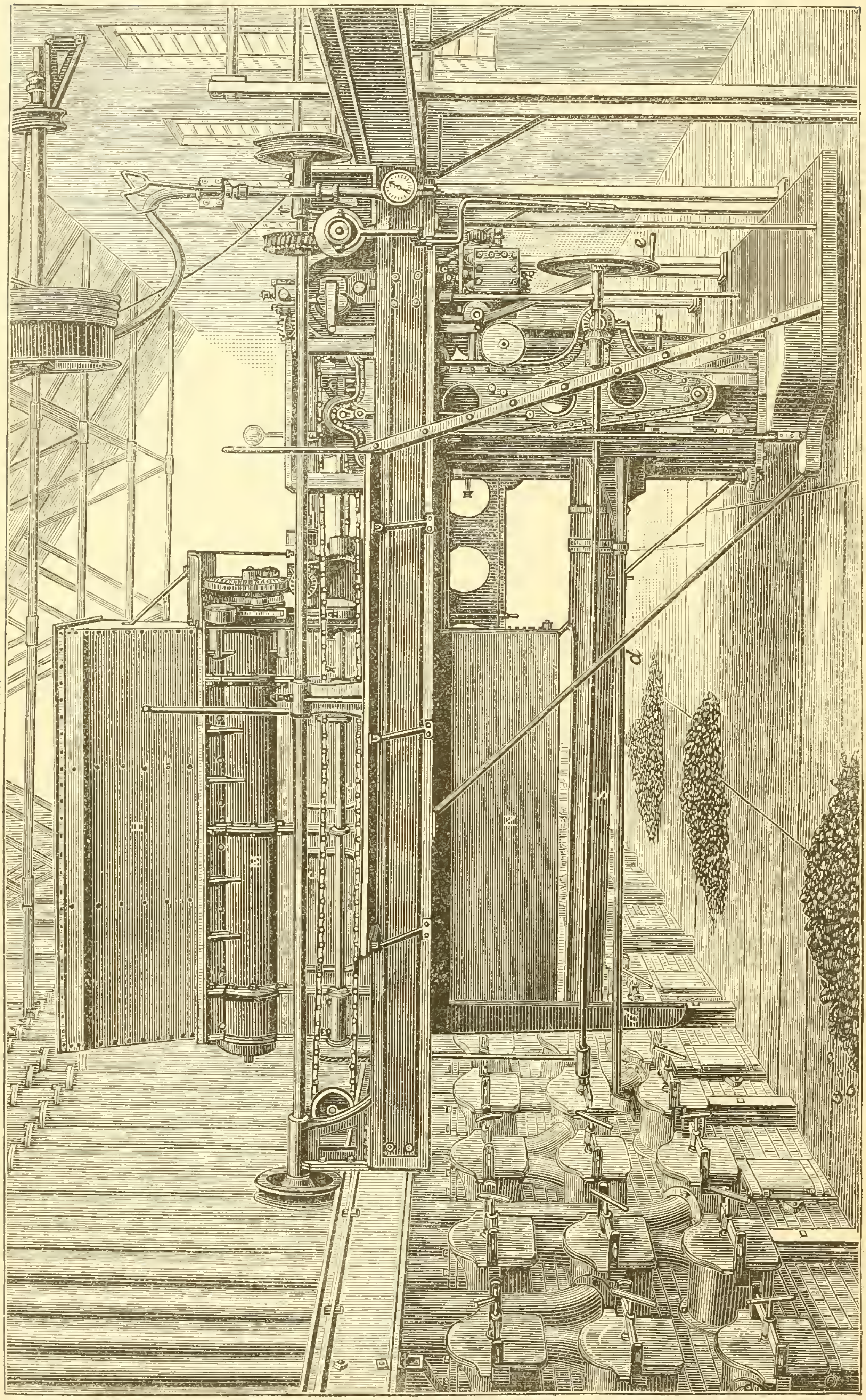

1960.




1961.



the retort raked into an even stratum. The lid, previously luted, is now quickly jointed on to the retort-mouth. It must be obvious that the loss of gas by this simple method is very trifling, the whole operation not occupying more than 40 seconds; whereas, when the shovel is used, the coal is thrown in so much by degrees that more gas is lost, owing to the greater length of the operation, and the heat producing some effect on each separate shovelful; in either case the loss is considerable.



1962.

Previous to drawing the charge, the lids of the retorts are loosened, and a light applied to the issuing gas, beginning at the upper retorts. This precaution is necessary to prevent explosions.

*Rowland's Retort-Stoking Machinery.*—Rowland's retort-stoker, or "power retort-worker," is represented by Fig. 1962. The following description is from a report of the engineer of the New York Gas-Light Company: "It is capable of being, and often is, worked at the rate of drawing and charging 20 retorts in as many minutes, cleaning them perfectly and depositing the coal evenly therein. If loaded with the aggregate coal for say 20 retorts, the receptacle will be emptied when the last retort is charged, and each individual retort will have received its proper quota, and this without any attention from the operator whatever. The ability to unequally divide the charges is such that one retort may receive say 300 lbs. of coal, and the next one 150 lbs., or any number of pounds intermediate to the two sums, by simply turning an index-wheel, which can be accomplished in 20 seconds. The apparatus is briefly a locomotive carriage traveling by preference upon an elevated rail, although it would be equally as effective on a surface rail, the former being adopted in order to keep a floor space for the coke-trollies. Its functions are to travel the length of the retort-house, automatically divide the coal into specified quantities, put the same into the retorts, and deliver the coke into the wagons. The power to perform the various functions is conveyed by means of compressed air, which performs the triple duty of working the machine, creating ventilation by the exhaust, and tending to keep the operators cool, and lastly of affording a means of preventing the rake and handle of the drawing portion of the apparatus from becoming hot and melting, which end is obtained by causing the air to pass through the handle and hoe, thus carrying off the heat and obviating the constant and rapid destruction of the rake or hoe, and the handle to which it is attached. The drawing part, of which the rake *d d* is the chief implement, is fixed to a traveler, and can be advanced into and returned from the retort by the chain *c c*, being in gear with pulleys, the motion of which can be readily reversed. The first effect of the inward pull of the chain is to lift that part of the traveler to which the rake is adjusted and fixed (to suit the height of the retorts to be drawn), and the continuation of the pull takes the rake so lifted in over the charge, as far as the operator thinks fit; he then reverses the gear, the action of which not only brings the hoe down through the coke to the floor of the retort, but brings it out with as much of the charge as had been overreached. There is a very simple movement by which the operator can swerve the end of the rake to the right or left as it recedes from the retort, by merely revolving the wheel *e* to the right or left, as the case requires. Notwithstanding this deviation from the centre line of the retort being induced by the operator, when the rake is re-inserted in order to remove every vestige of the charge, it takes automatically as to height and bearing the same path that it was set to for the first stroke; therefore the fouling of the mouthpiece is rendered impossible, without any trouble on the part of the attendant. In fact he has nothing to do but to cause the rake to advance, and set the 'monkey's tail' (as the men call it) so as to determine whether it shall return in a line coinciding with the centre line of the floor of the retort or to the right or left of the same.

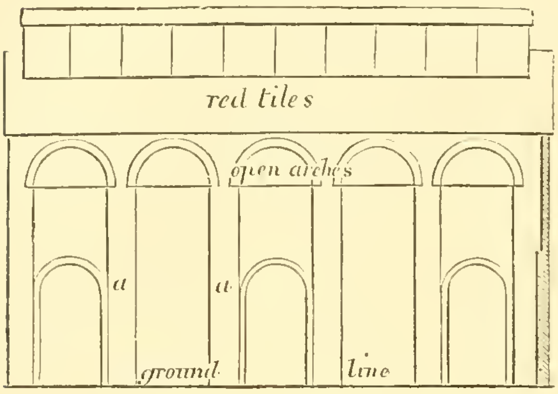
"The charger *S* is a case or box the shape and length of the retort, but as much smaller as necessary for clearance. It has a sliding bottom, and when loaded with a maximum charge is really full. If the retort is not in a condition to work off so much coal, the measuring cylinder within the case *M* is set in a few seconds so as to take from the hopper *H* the quantity that the man in charge of the retorts considers to be enough. The dropping of the coal into the scoop after it is measured is carried out in this manner: The shoot *N* can be adjusted in the same way as the scoop to the height of any retort in the range. It also automatically moves a few inches upward every time the scoop is sent in, to allow the heel to pass under its edge, and just before the meter is about to deliver a charge into the scoop (just withdrawn from the retort) it is lowered a few inches by the motion of the same cam that raised it. By this time the slot or opening in the measuring cylinder through which it received the coal from the hopper *H* is downward, and the charge pours down the shoot *N* into the scoop, which has a slotted opening along its arched top into which the shoot fits dust-tight. A few seconds after this, the measuring cylinder still revolving, the cam on the shaft that carries this cylinder lifts the shoot *N* (as before mentioned) above the scoop. The advance-gear is now thrown in and the loaded scoop inserted. Immediately this is accomplished, a pinion gearing in a rack underneath the sliding bottom is by a self-acting arrangement set in motion, and runs the bottom back from under the coal, leaving it deposited evenly on the floor of the retort. The body or case is now by the reverse action of the gear returned to the bottom, and being *in situ* is ready for another charge, which by this time is nearly measured out by the meter *M*. The hose-reel *R* gives freedom of motion without having to reconnect. The hose is wound on by a counterweight, and off by the pull of the machine; but to prevent any strain on the hose, a line that winds on and off with it is made fast to the machine. The air, which is compressed to about 40 lbs. to the square inch, comes to the hose through the hollow shaft of the reel. When the coal is deposited in front of the retorts, as is generally the case in large works in this country, the large hopper *H* is not required, the coals being lifted to the meter *M* by a chain of buckets, or an equivalent, as the machine advances."

*Retort-House.*—Figs. 1963 and 1964 represent a retort-house built of brick, for coal-gas, upon the most simple construction, and well adapted for a town requiring 70,000 cubic feet of gas for the supply of each night in the winter season. Being without coke-cellar, the charges must be drawn into wrought-iron barrows, the contents wheeled into the open air, and spread abroad to cool. The outside walls are calculated to give the greatest security with the least possible material. The piers *a a* are 18 inches thick at the base, projecting 4½ inches (on the outside) from the brickwork filling the space between them. Half way up the walls there is a 4½-inch offset, which leaves the thickness of the panels 14 inches below and 9 inches above the offset. The roof is of wrought-iron; the ventilator is of wood. The retorts are set 5 in one oven, making 40 retorts, which will allow two extra benches for repairs. In 24 hours, 30 working retorts will carbonize 240 bushels or 180 cwt. of coal, and produce 78,000 cubic feet of gas. In some places, where little gas is required in the

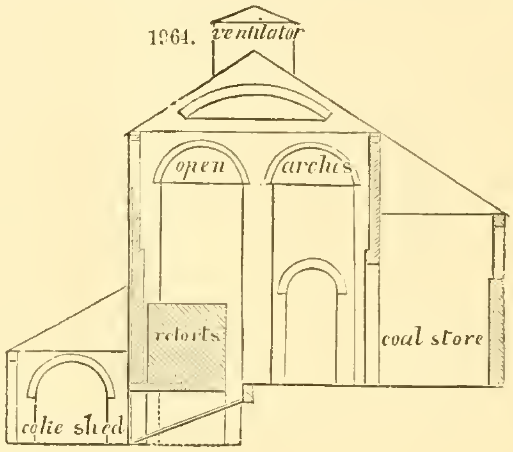
summer season, one-half or even the entire number of retorts may be set three to one oven with economy.

In the example, Fig. 1964, advantage was taken of sloping ground to form a coke-shed, which saved a considerable quantity of brickwork. The charge, as it was drawn, fell through the space in front of the retorts, and was carried by an inclined plane into the shed behind. This house is considerably larger than that described in the last example, and is furnished with a coal-store. It may

1963.




1964.

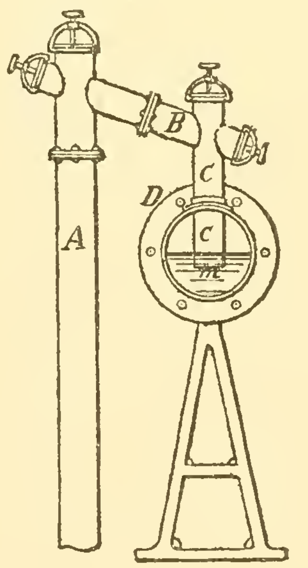



perhaps be as well to state here that coal from which gas has to be distilled should if possible be always kept under cover, because, when moisture is present, the hydrogen arising from the decomposition of water will deteriorate the quality of the gas. It is, therefore, a matter of economy to construct a sufficient shed to preserve the coal in a dry state. The house contained 55 retorts, allowing two benches of 5 retorts each for repairs. The coal carbonized by the remaining 45 retorts was 360 bushels or 270 cwt. in 24 hours, producing 117,000 cubic feet of gas.

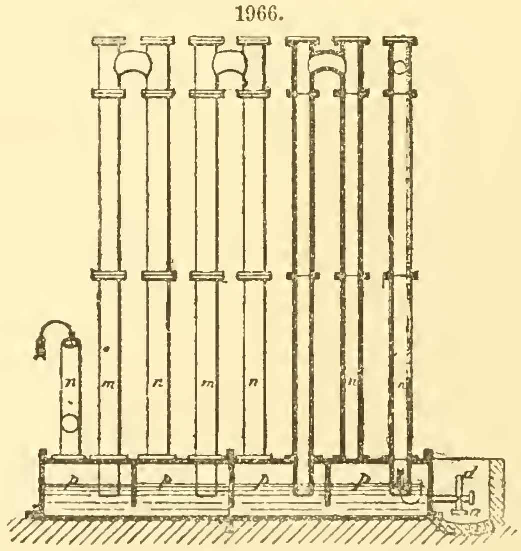
Chimneys.—It is necessary to have a good draught, as the coke of the furnace has to be intensely heated. It is therefore necessary not only to confine the fuel within proper limits, but constantly to supply it with the requisite amount of oxygen, to be derived from the atmospheric air presented to the fuel. It is absolutely essential, then, that the chimney be so constructed as to accomplish the object in view. The utility of the chimney consists not only in its height, but in its area being constructed in like proportion, so that the heated air and products of combustion may pass off with freedom. Dampers should be placed in the settings, and not in the main flue; as the object is to have a good draught throughout the whole of the settings, and to check each bed carefully by its damper. The height to which chimneys are built depends on the amount of gas to be made. For small works, producing from three to four million feet per annum, a chimney 35 feet high, with an opening 16 inches square, is sufficient. The height of the chimney increases according to the capacity of the works, until it attains a height of 120 feet, with an area of 20 or 25 square feet, which is about as high as chimneys for gas-works are ever built. (See Chimneys.)

Hydraulic Main and Ascension-Pipes.—By the "hydraulic main" is understood a vessel with which are connected the ascension-tubes leading from the retorts, and it is the first element of the con-

1965.




1966.



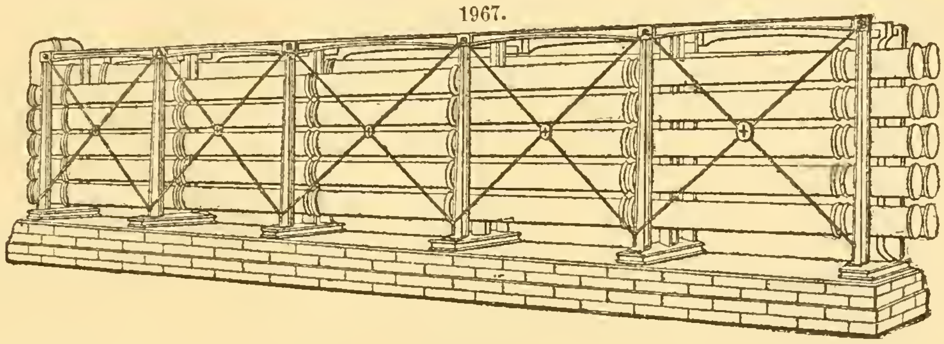
densing apparatus as already described. The hydraulic main is more commonly made of wrought-iron, as cast-iron breaks too easily. The thickness of the wrought-iron is one-fourth or three-eighths of an inch, depending somewhat on its diameter. The diameter of the ascension-pipes is on an average from 4 to 7 inches. The hydraulic main is placed on the top of the furnace, and is supported on cast-iron stands or crutches, which are mounted on cast-iron piers placed over the piers of the ovens,

so that the main may be distant from the front of the settings, and from the excessive heat there present.

Fig. 1965 shows the mode of connection between the retorts and the hydraulic main. *A* is the ascending or stand-pipe; *C*, the dip-tube carried downward into the hydraulic main; *D*, the main, and *m*, the liquid—viz., tar, or, at the first starting of a gas-works, water.

Condenser.—The object of the condenser has already been stated. The form of the most common air-condenser is represented by Fig. 1966. The inlet-pipe is in connection with the hydraulic main, the outlet-pipe being connected with the exhauster. The stand-pipes are connected with each other at the top, and rest in a large cast-iron tank, which, by means of partitions, is divided into compart-

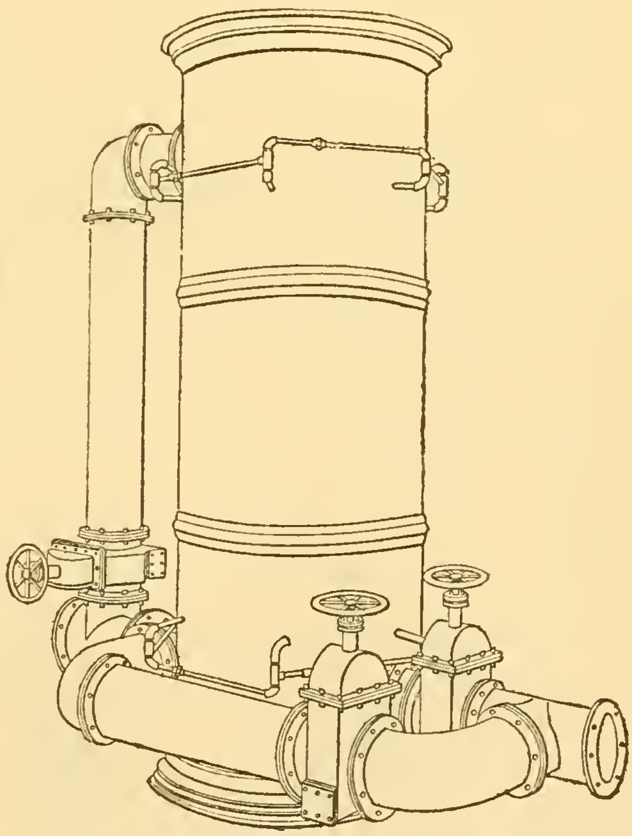
1967.



ments not communicating with each other, being hydraulically locked; each compartment being fitted with an inlet *m* and outlet *n*.

*Horizontal condensers* have lately grown into use, and are considered, when of considerable length, to be the best means for reducing the temperature of the gas and absorbing its impurities. Fig. 1967 represents a horizontal condenser invented by Mr. D. A. Graham, who claims that by his apparatus he removes about 16 lbs. of sulphuretted hydrogen and 5 lbs. of carbonic acid for every ton of coal carbonized. The condenser represented is 65 feet long, and consists of 650 feet of 16-inch pipe, which, with the inlet and outlet pipes, makes the combined condensing surface equal to 4,000 superficial feet. At the Beckton works, London, each condenser consists of 2,600 feet of 12-inch pipe for a maximum make of 2,500,000 feet of gas, or about 3 feet surface per 1,000 feet, per diem.

1968.



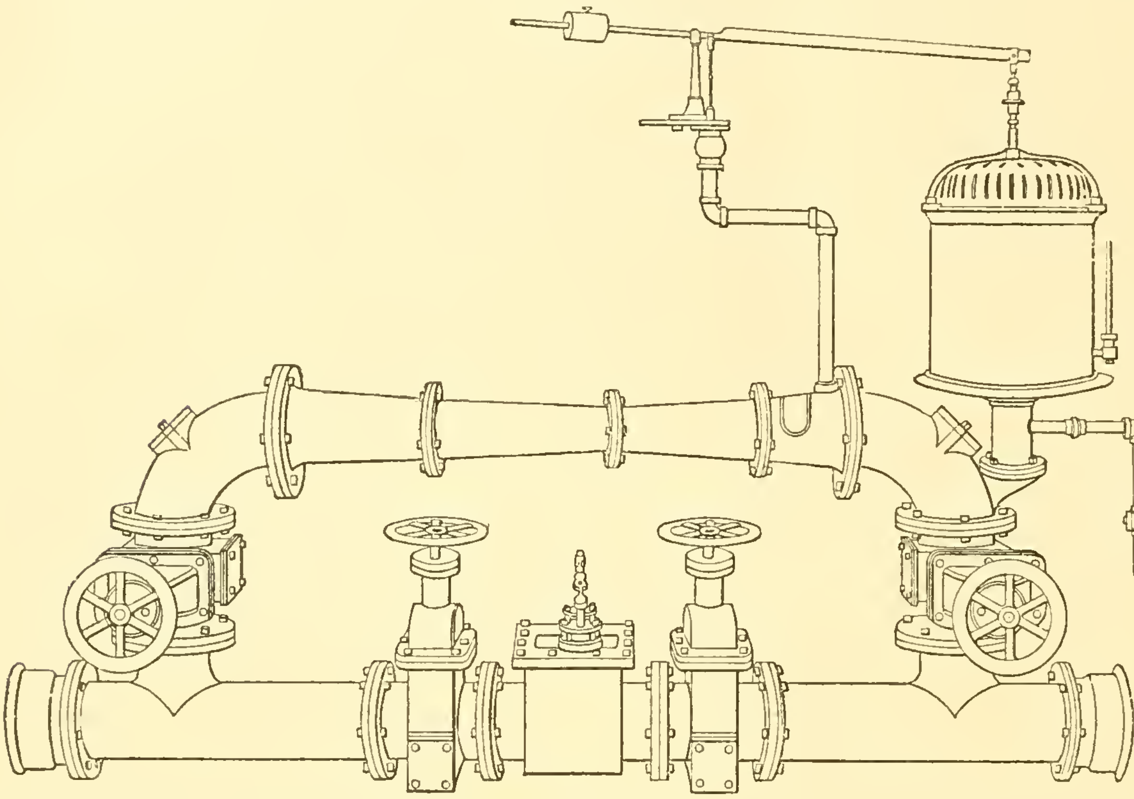
*Mackenzie's Surface Condenser* is represented in Fig. 1968. This condenser has for its object the gradual cooling of the gas. Cold water is admitted at a number of places at the bottom of the condenser, and surrounds the tubes. The gas, being admitted at the top, comes in contact with a surface of nearly equal temperature, and moves slowly downward; the surface constantly growing colder as it descends, until the desired condensation is effected. The current of gas is always downward with the gravitation of the heavy particles, causing the accumulations to be deposited in the tar-well below.

*Pelouze and Audouin's Mechanical Condenser.*—A novel process of condensation has been devised by MM. Pelouze and Audouin, which consists in forcing the gas at great velocity through numerous small orifices. The jets so formed are brought in contact with a surface placed near to the perforations, and against this the globules held in suspension break and unite, acquiring thus a weight sufficient to cause their precipitation in the form of liquid against the sides of the apparatus. The essential portion of the device which forms the condenser proper consists of a chamber of polygonal section formed of two vertical concentric portions. These parts are similar, each being composed of two metallic plates placed a short distance apart. The interior plate is pierced with a large number of small holes disposed symmetrically with relation to the vertical axis of the chamber. In the external plate are made several much larger rectangular orifices, so arranged as to come opposite the non-perforated parts of the inner plate. It will be obvious that when the vesicles entrained by the gaseous jets strike the solid portions of the external plate, they are broken up and run together in liquid form down the surface of that plate, the gas meanwhile escaping by the rectangular orifices. In the other side of the chamber a similar action occurs, and this completes the operation. The action of the apparatus depends on the shock of the gaseous

molecules on the plates. The gas passes up into and through a cylindrical chamber, which is suspended and balanced by a counterweight. After traversing the sides of the chamber, the gas finally escapes by a pipe.

THE EXHAUSTER is usually placed between the condenser and the scrubber, and combined with it there is a pressure-gauge in direct communication with the hydraulic main. Mr. Joseph A. Sabbaton, the engineer of the Manhattan Gas-Works, has shown how great is the advantage of an exhauster with clay retorts. The following is a trial reported by him:

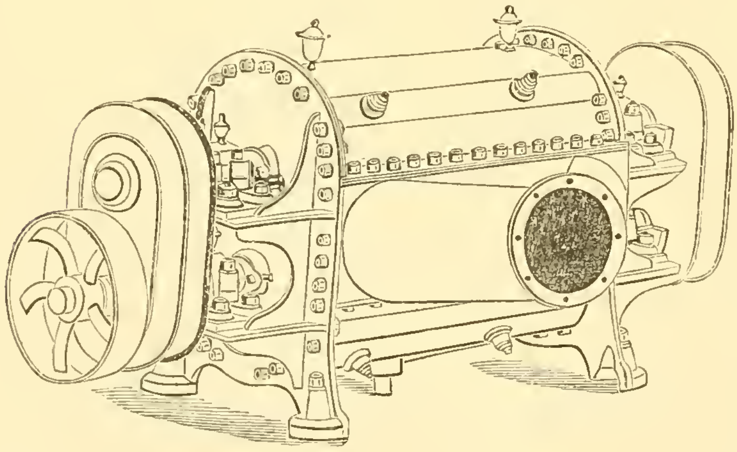
1969.



"Owing to the engine being idle for repairs to the boiler, the exhauster was not in operation during $3\frac{1}{2}$ days. The amount of gas manufactured was by this reduced 115,000 cubic feet per day, the average make before the exhauster was stopped being 1,618,000 cubic feet per day. This would show a difference in favor of the exhauster of about 7.6 per cent., or 772 cubic feet per ton. After the exhauster was again started, the average daily make (during a period of five days) was 1,665,000 cubic feet per day. This would show a difference in favor of the exhauster of about 162,000 cubic feet, or 10.7 per cent., equal to 1,016 cubic feet to the ton of coal. Taking the mean of two trials, the difference in the yield of gas, when clay retorts are used, may be taken at 9 per cent. The daily amount of coal used in each of the three periods varied but a few pounds, and the inlet-gauge to the exhauster showed equal vacua during the first and last of the trial."

*Mackenzie's Steam-Jet Exhauster* is represented in Fig. 1969. In constructing an instrument of this kind the object is to get the largest result with the least expenditure of steam. Baking or cooking the tar must be avoided. Actual test has proved that the gas can be successfully handled by this instrument up to 12 inches pressure with a minimum of steam. The steam, being thoroughly incorporated with the gas, takes up a large portion of sulphur and ammonia, and if properly condensed will thoroughly wash the gas without additional water. If a surface condenser is used, nearly all the ammonia now deposited in the purifiers, with that taken out by washing, will be contained in about one-tenth the amount of water, which is important when the ammonia is saved. The steam passes through the jet-pipe with a velocity due to its pressure, and creates a current from the retorts in the same direction. The steam, and such impurities as have combined with it, are taken out by condensation. The amount of steam is regulated by the make of gas operating a governor, attached directly to the steam-valve. A self-acting by-pass, to allow free passage of the gas in case the exhauster is not in use, is provided, and valves to admit of ready access to all parts.

1970.



*Root's Improved Rotary Exhauster* is shown in Fig. 1970. It is in use at several of the large gas-works in this country. The blower operates by a regular displacement of air, measuring and forcing forward a definite quantity at each revolution. The power applied is all used either in driving the machine or forcing forward the air. (For construction, see BLOWERS.)

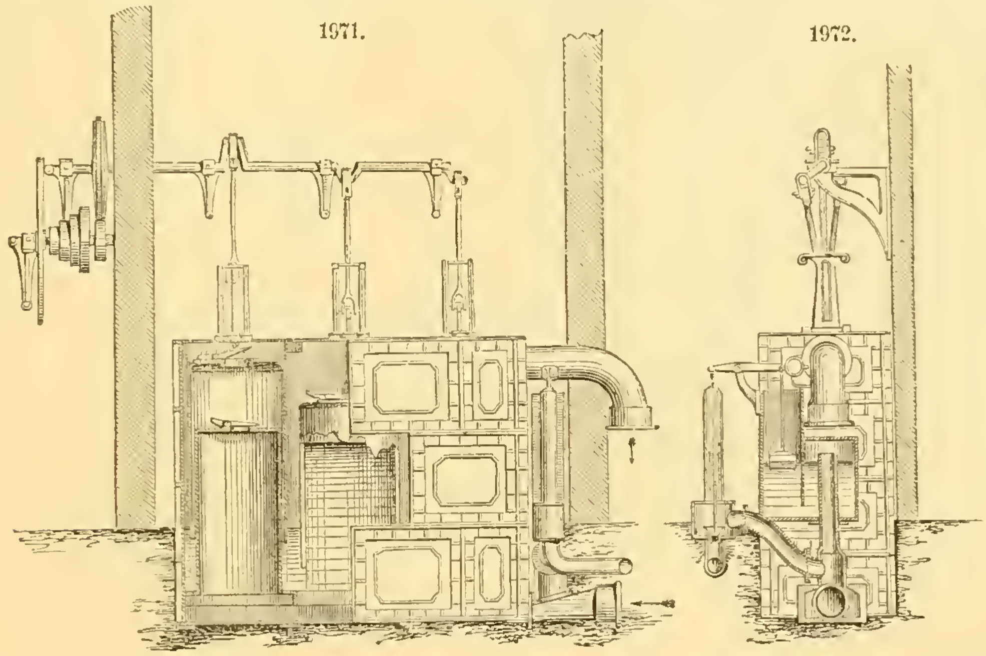
The horse-power required to drive different sizes of these exhausters is as follows, the weight of the exhauster being given without engine or bed-plate: 375 lbs., $\frac{1}{5}$ h. p.; 525 lbs., $\frac{1}{2}$ h. p.; 1,650 lbs., 1 h. p.; 3,500 lbs., $2\frac{3}{4}$ h. p.; 5,575 lbs., 4 h. p.; 7,950 lbs., $5\frac{1}{2}$ h. p.; 10,800 lbs., $8\frac{1}{4}$ h. p.

Figs. 1971 and 1972 represent a gas-exhauster designed by Mr. Methven for the Commercial Gas Company's Works, London. This machine consists of three vertical wrought-iron cylinders, which are made to rise and fall in a tank containing water, by the revolution of a treble crank-shaft with connecting-rods and guides. Each of these cylinders is inverted over a chamber of cast-iron, the interior of which communicates with the hydraulic main. The top of each chamber is provided with a flap-valve, which allows the gas to escape into the movable cylinders during the ascent of the latter by the action of the crank. The cylinders have valves on the top, similar to those in the cast-iron chambers, which during the descending stroke allow of the discharge of the gas into the upper part of the external cistern. From the cistern a main leads through the purifiers to the gas-holder, and the gas is thus pumped out of the retorts and discharged into the gas-holder, independent of any amount of pressure required to be overcome in its passage.

The velocity of this machine is regulated by the use of conical strap riggers to suit as nearly as possible the amount of gas being generated; but in order to avoid the possibility of the pressure upon the hydraulic main becoming less than that of the surrounding atmosphere, and the gas thereby becoming impoverished by the admixture of atmospheric air, a regulating machine is attached to the exhauster, which by self-action maintains that pressure perfectly uniform. The regulator consists of

1971.

1972.



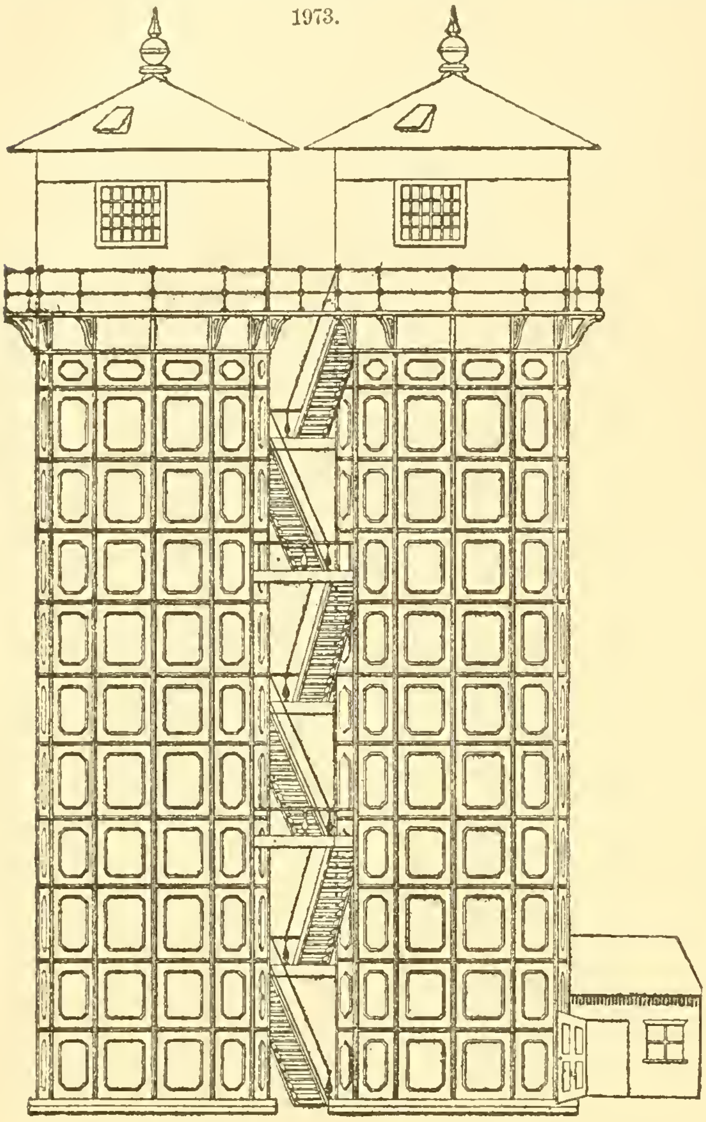
a chamber which communicates alike with the inlet and outlet passages of the exhauster, and which is divided by a valve or conical plug acted upon by a float sustained in water, under the immediate influence of the exhausting power of the machine. The action of the float is communicated to the valve with the smallest amount of friction by a lever and connecting-rod with the usual adaptation of a water-joint; and the effect is that, when the machine from any cause is reducing the pressure of gas upon the hydraulic main below that of the atmosphere, and thereby causing a partial vacuum in the retorts, the float of the regulator is by the same means depressed, and the communication between the inlet and outlet of the exhauster thereby opened to a sufficient extent to restore the equilibrium. Equilibrium is maintained between the interior of the hydraulic main and the atmosphere during the various velocities. The pressure has been increased to 48 inches of water without any sensible variations in the effect upon the gauge indicating the pressure upon the hydraulic main. The highest speed of this machine is calculated to discharge 60,000 cubic feet of gas per hour at a pressure of 30 inches.

WASHER.—The washer used by the Manhattan Gas Company consists of a series of 36 cells, 3 feet square and 10 feet high, each supplied with two jets of water, which enter at the side and are thrown into spray by impinging against an iron plate; the gas passes through the entire series. A system of washer has been invented by Mr. Cattrels, wherein the gas is caused to pass through long narrow channels situated just beneath the surface of the water; consequently fresh surfaces of each globule of the gas in its transit are brought into contact with the water, by which means the ammonia is eliminated. Washers are not so generally used to eliminate ammonia as are scrubbers.

SCRUBBERS.—Fig. 1973 represents one of Mann's scrubbers, constructed by Messrs. Walker of London. The size is usually so proportioned as to be about one-third its height. For large works the dimensions are 60 feet in height by 18 feet in diameter. The figure represents two of a set of five scrubbers used at the London Gas-Works. The penthouse on top of the tower contains the gearing, the reservoir, and means of controlling the supply of water.

"Within the scrubber is a series of trays which support layers of coke, while at the extreme top is the contrivance for distributing the water or weak liquor, by means of revolving arms perforated with small holes, the motive power being imparted by means of a cog-wheel and shaft connecting with an engine. In order to occasion a still further distribution of the liquid, the water or weak liquor distributed by the perforated arms falls into a layer of brushwood, which is also sometimes made to revolve, and thus the liquor finds its way on to the first layer of coke in the form of fine drops. The liquor then falls slowly through from tier to tier, becoming stronger and stronger as it descends."

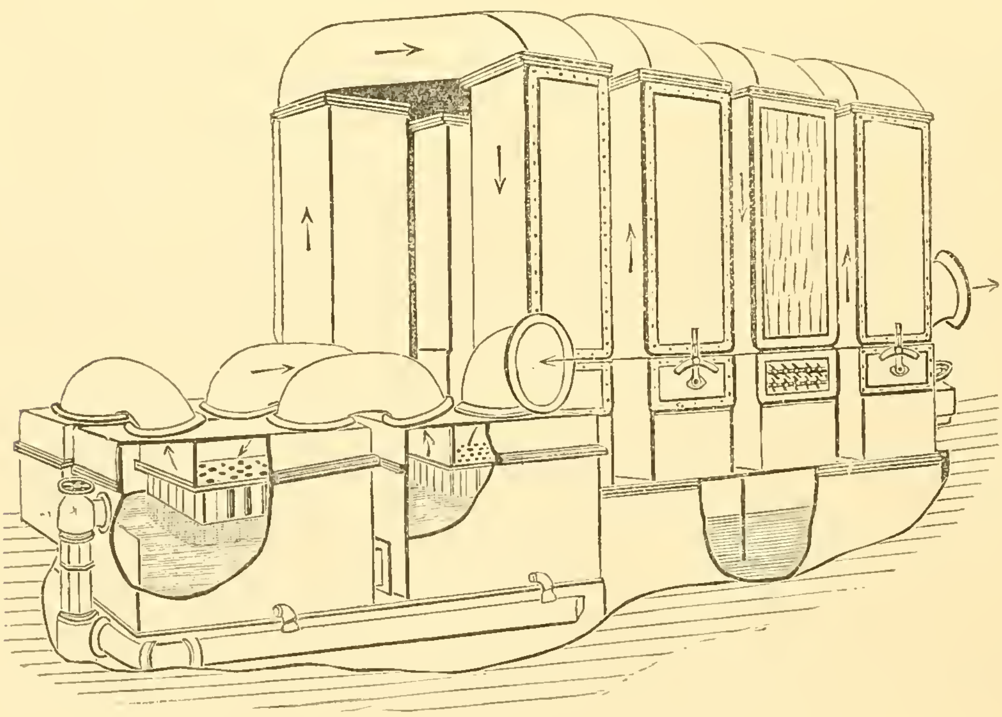
1973.



*The St. John and Rockwell Apparatus*, illustrated in Fig. 1974, takes the place of condenser, washer, and scrubber, and avoids the use of any water save that condensed from the gas. The gas enters the first box, which is made absolutely tight, except at the dip-tubes; it is then forced down tubes submerged in the liquid products of the coal, which are brought forward by a separate pipe from the hydraulic main to a given depth. The tubes have at their lower ends a fine meshwork, so that the volume of the gas is divided many hundred times, insuring the requisite action. After passing this series of seals, the gas is then conducted to another of the same character, and so on, until it has passed through the four boxes. It then enters the first of the series of upright pipes, which are provided with a lattice-work and corrugated plates (as shown by the open pipe in the figure), and, after proceeding through the whole series, makes its exit to the purifier. The tar is removed by cohesion; the ammonia and naphthaline by solution.

Prof. Charles F. Chandler tested this apparatus at the works of the Harlem Company for a week, using 163,120 lbs. of Pennsylvania and 470,445 lbs. of Murphy Run coal. The yield averaged

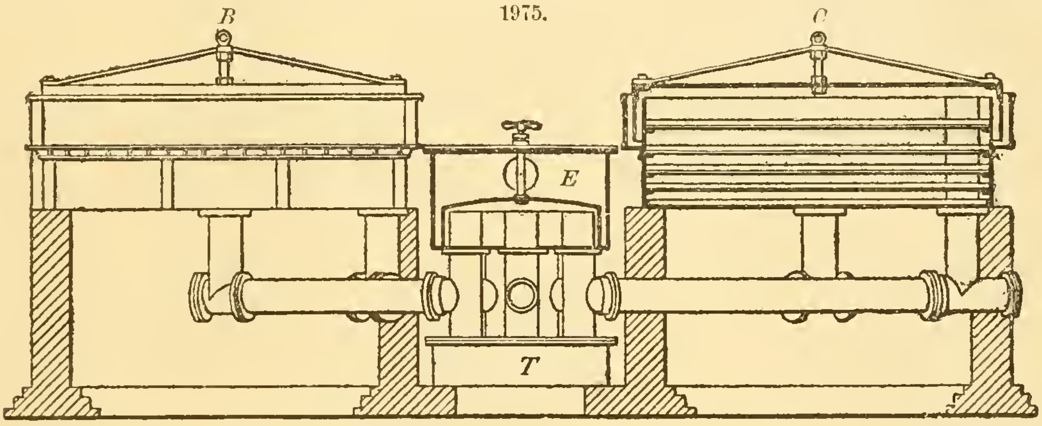
1974.



10,897 feet of 17.06 candle gas, which contained, after being purified with oxide of iron, only 2.65 grains of ammonia and 23.58 grains of sulphur in 100 cubic feet.

PURIFIERS.—Malam's improvement of Phillips's apparatus is generally employed for either oxide of iron, lime, sulphate of iron, or other solid compounds used as purifying agents. His arrangement, as generally applied, consists of four purifiers in connection with each other, and with a cen-

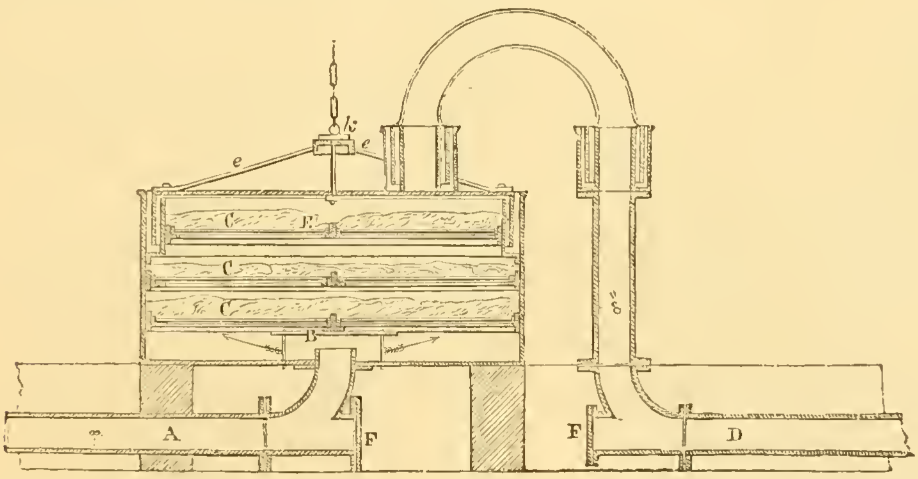
1975.




tral valve by which they are controlled in such a manner that, three of them being in operation, the fourth is shut off, thus affording every facility for discharging the foul material and recharging the apparatus for purifying.

Fig. 1975 represents two of a set of four purifiers in connection with a central valve, that marked *B* in elevation, the other, *C*, in section. The centre valve is also shown in section, and consists of

1976.

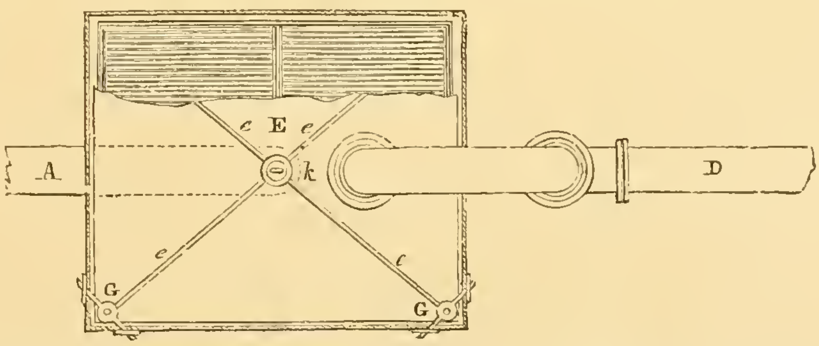



a closed cylindrical vessel *E*, supported by nine vertical T-pipes, open at the lower ends and standing on the tank *T*, which is filled with liquor, and receives any condensation, thus serving as a siphon for all the connections.

Although, as has been said, lime-purifiers have almost entirely gone out of use, still, as there remain a few, a description of the old apparatus employed will be of interest.

In Figs. 1976 and 1977 are represented an elevation and plan in section of one of a series of

1977.

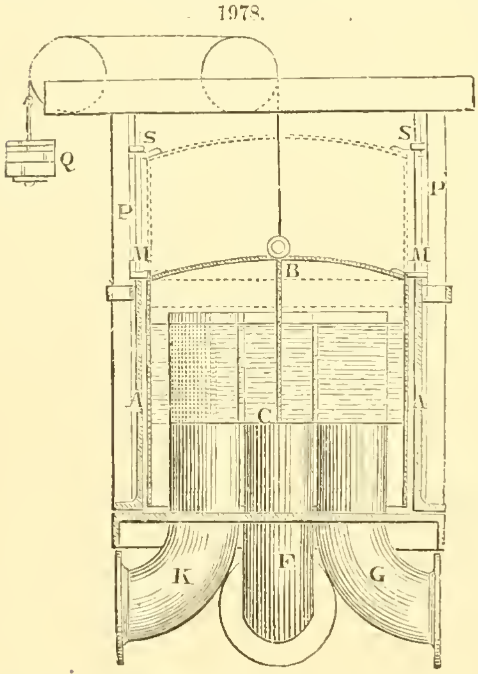



three "dry-lime" purifiers, through which the gas passes successively; in other words, they are "worked together," and, though separate, may be considered as one machine. *A* is the inlet-pipe from the wash-vessel, entering at the bottom of the first purifier. *B* is a plate of sheet-iron, about 2 feet square, placed over the mouth of the inlet-pipe, to separate the stream of gas in some degree, as well as to prevent any lime from falling into the pipe. *C C C* are the layers of hydrate of lime, spread upon screens formed of an outside frame, and a number of round rods or wires about five-

sixteenths of an inch in diameter, stretched across them in one direction, to afford greater facility for clearing, with a small interstice between each. These screens are placed one over another, in three tiers, from 6 to 8 inches asunder; each tier may consist of four screens for the convenience of lifting them out and replacing them. *D* is the outlet-pipe leading to the second purifier. This arch-pipe is made of thin plate-iron, sealed at each end by a water-joint; because, when the lid has to be lifted, this arch-pipe must be removed, and any other kind of joint would be troublesome. *E* is the lid of the purifier, also sealed by a water-joint; *e e* are round five-eighths rods, keyed at one end into the keep-ring *k*, and riveted to each corner of the lid at the other; a chain is hooked on to the ring *k*, and passed over a pulley to a balance-weight, by which, and the rods just mentioned, the lid is lifted. *F F* are blank flanges or bonnets, through which, when removed, the pipes are cleared from any deposited impurity. *G G* are clamps, to keep the lid of the purifier in its place.

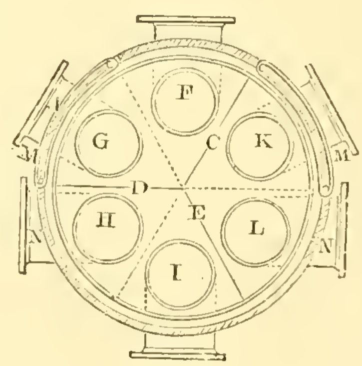
Figs. 1978 and 1979 represent the hydraulic valve just mentioned. *A A* is a cast- or sheet-iron tank, 3 feet in diameter and 2 feet 6 inches deep, generally filled with tar to within 6 inches of the top. *B* is a light sheet-iron or tin gasometer-shaped vessel of less diameter, divided into three partitions by the plates *C*, *D*, and *E*, of less depth than the rim. *F* is the pipe from the wash-vessel or condenser. *G* is the pipe leading to the first set of purifiers. *H* is the outlet or return pipe from them. *I* is the pipe leading to the meter and gasometers. These pipes, in the present position of the valve, are all in action. *F* and *G*, being in the same partition, communicate with each other, as do *H* and *I*, for the same reason. When the purifiers have to be changed, the vessel *B* is lifted up, until the bottom of the partition, at *C* in the elevation, Fig. 1978, clears the pipes, the outside rim remaining immersed in the tar (the stops *S* on the guide-rods prevent it from being lifted too high), and turned partly round until it occupies the position shown by the dotted lines in the plan, Fig. 1979. The guide-rods *M* pass through openings *N*. *K* and *L* are the pipes connected with the second set of purifiers thrown into action and into communication with *F* and *I*, when the vessel *B* is shifted to the position shown by the dotted lines in the plan. *P P* is a wooden frame supporting the pulleys and balance-weight *Q* to assist in lifting the vessel *B*, which while in action is kept from rising with the pressure of the gas by a bolt.

1978.




In preparing the lime for the purifiers, it ought to be beaten, well sifted, and water added until, by compression in the hand, the lime will just adhere; if any lumps remain, their outside only will be acted upon; when broken, they will be found untouched in the inside; and although such lumps may be used again, it is always better to systematize the process in the first instance, and prevent even the smallest waste.

1979

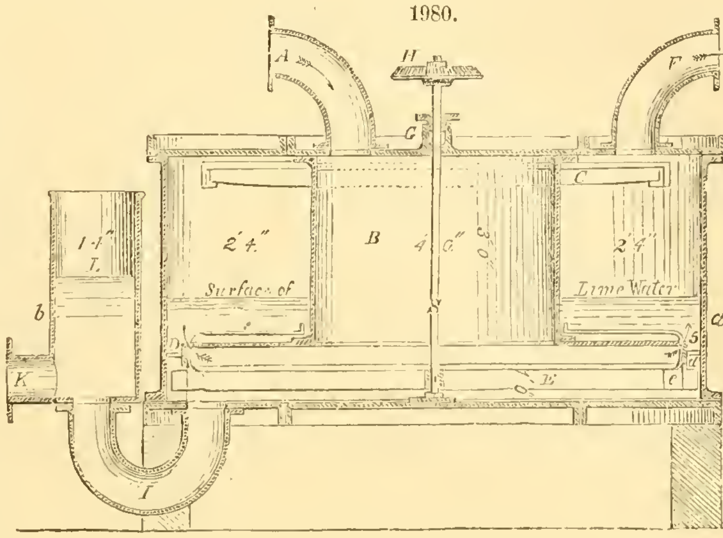



*Lime-Water Purifier.*—Fig. 1980 is an elevational section of a lime-machine, and Fig. 1981 a plan through *a b* in Fig. 1980. *A* is the inlet-pipe through which the gas passes into the chamber *B*, which is 4 feet in diameter, jointed to the lid of the purifier, and supported upon two cast-iron beams *C*. On to the bottom flange of this chamber a circular ring of thin wrought-iron plate is riveted, of such diameter that its outside rim will be within 5 inches of the tank of the purifier. *D* is a hoop supported from the tank by bolts *d d*, etc., having its upper edge level with the before-named plate, and its lower edge 4 or 5 inches below it. The space left between this hoop and the ring is three-eighths of an inch, through which the gas (after having overcome the pressure of the column of water contained in the tank, plus the pressure in the gasometers) will pass, and bubble up through the lime-water. *E* is an arm made to revolve on the spindle *S*: the parts *e e* of this arm continue through the aperture and over the ring, serving to keep the lime from settling or obstructing the passage of the gas. *F* is the outlet for the purified gas. *G* is a stuffing-box, through which the spindle *S* passes. *H* is a mitre-wheel, connected to a water-wheel or steam-engine for turning the spindle. *I* is a pipe through which the lime-water is drawn off when it has become saturated with the impurities of the gas. It will be observed that by this contrivance the water can be completely drained off, by opening a slide-valve bolted to the flange of the pipe *K*, without suffering the gas to escape along with it, because a column of water will remain in the tube *I* equal to the height of the bottom of the tank, measured from the inner radius of the curve of the tubes, viz., 12 inches, which is always more than sufficient to overcome the pressure of the gas in the purifier when the valve on the inlet-pipe *A* is closed, which should be done before that at *K* is opened. *L* is a cylindrical vessel, open at the top, for filling the purifier; it also serves to show the quantity

of water required; when the machine is at work the column contained in the vessel will be higher than that in the tank, in proportion to the pressure of gas in the gasometers, usually about 3 inches.

The lime-water may be mixed in a cistern, and drawn off by a hose into any of the machines, care being taken to keep the mixture well agitated while passing. The proportions are one measure of paste-lime to three of water; that is, to every 5 bushels of paste-lime about 120 gallons of water must be added. The size of the lime-machines ought to be so regulated that they will contain sufficient lime-water to purify the quantity of gas made in 24 hours, without having occasion to fill them higher than the water-line shown in the engraving. Four lime-machines are necessary, two being in action and two out, alternately. When that machine is spent through which the gas first passes, it is shut off, and a third opened, the second being left to perform the duties of the first, and so on.

1980.

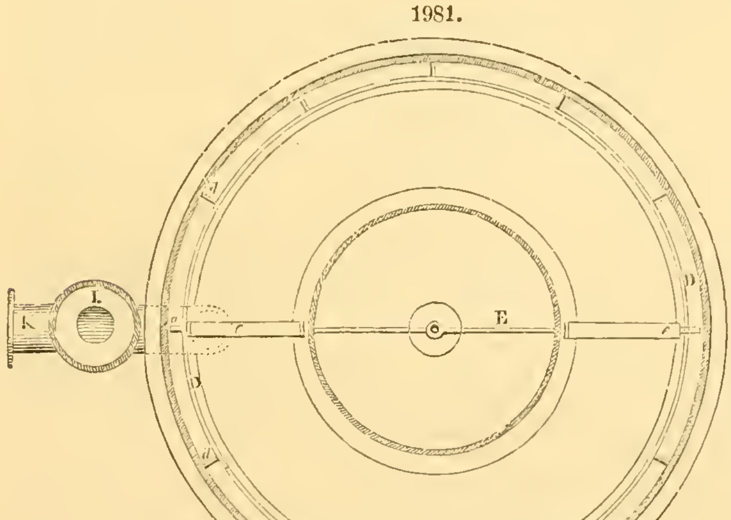



The quantity of lime required for the complete purification of coal-gas varies very much with the quality of the lime and the gas; that coal which produces the greatest volume of sulphuretted hydrogen from the presence of iron pyrites will require the most lime. As the best means for arriving at a proper practical conclusion, we annex the quantities used at different gas-works in various places.

At the Imperial Gas-Works, London, one bushel of quicklime purifies on an average 10,000 cubic feet of gas, the price of lime being 7*d.* per bushel. The lime is used both as a hydrate and in the fluid state, in the following proportions: For the purification of 1,000,000 cubic feet, the produce in the winter season of 24 hours, 80 bushels mixed as "dry lime," and 20 bushels mixed into a fluid: this quantity performs its part thoroughly. At Cheltenham, 1½ bushel of quicklime, reduced to the state of a hydrate, will purify 10,000 cubic feet of gas perfectly; cost per bushel, from 5*d.* to 6*d.* At Birmingham, the purification of 1,000 feet costs, in lime and labor, from 1¼*d.* to 1½*d.*, but in reality not nearly so much, as the refuse is sold for two-thirds the original cost of the lime. Lias lime is used, and "dry purifiers." With the dry-lime purifiers at Chester, 1 cwt. 2 qrs. is required to purify 10,000 cubic feet of gas. The Welsh lime is used, its price being 13*s.* 4*d.* per ton; therefore the purification of 10,000 feet will cost 1*s.* without labor, which is about the average cost.

In making the dry-lime purifiers, that they may present a sufficient surface to the gas which passes through them, an excess, rather than a smaller area, should be given. A bushel of lime, when reduced to the state of a hydrate, contains very nearly 4,500 cubic inches: allowing that this quantity will purify 5,000 cubic feet, it follows that 12.5 square feet of screen surface is required, the depth of the lime being 2.5 inches. For retorts calculated to produce 300,000 cubic feet of gas in 24 hours, the purifiers should present a surface of at least 750 square feet. If three machines are worked together, each containing five screens, their dimensions may be 8 feet by 6 feet, and 3 feet deep, 4 bushels of hydrate of lime being spread on each screen. The surface presented by three machines like Fig. 1976, is 324 square feet; they were erected for an establishment producing 130,000 cubic feet of gas in 24 hours.

1981.




The work performed by a lime-water purifier is generally computed by its contents in gallons, and the head of water or pressure opposed to the passage of the gas through it. Taking the latter at a constant quantity of 8 inches, the computation is easy: 4,500 cubic inches of hydrate of lime (which, as before stated, is the quantity produced by reducing one bushel or 2,150 cubic inches of quicklime), mixed with 48 gallons of water, will purify 10,000 cubic feet of gas, if properly applied. In the example at Fig. 1981, the lime machine contains 316 gallons, which will hold in solution 13 bushels of hydrate of lime, and purify 65,000 cubic feet of gas. Two of these machines will therefore do the same work as the three dry-lime purifiers before mentioned, viz., 130,000 cubic feet.

Notwithstanding, however, that the quantity of lime required may be well known, it is necessary

to *test* the gas in its progress through the various purifiers. A saturated solution of the acetate of lead in distilled water is an excellent test, detecting the presence of the minutest quantity of sulphuretted hydrogen, and more convenient than the carbonate, from its complete solubility. Test-papers may be printed in the following form:

*Station and Date.*

| Crude Gas. | First Purifier. | Second Purifier. | Third Purifier. |
|---|---|---|---|

Lime-machine having been charged — hours with — bushels of — lime.

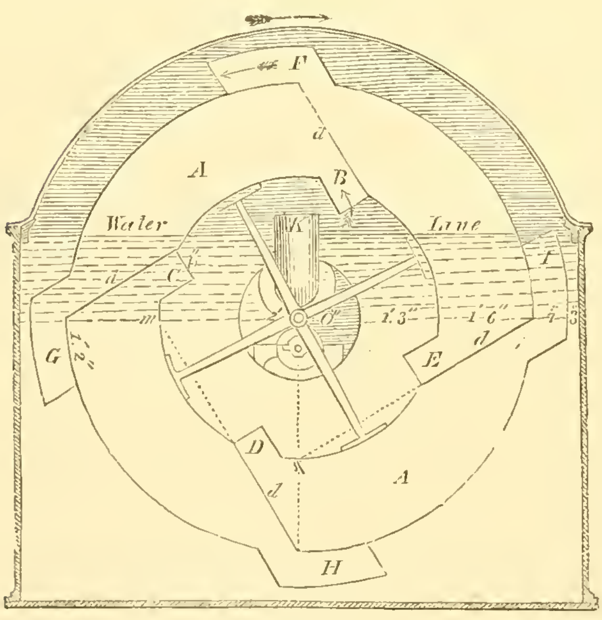
Fill a bladder, furnished with a stop-cock, full of gas from the main, before it enters the purifiers, and also one from each separate purifier, and let the bladders be labeled; with a camel's hair pencil paint the square marked Crude Gas with the test solution, and force the gas from the proper bladder upon it while wet; the paper will immediately be turned black; then paint the square marked First Purifier, and force the gas into it, and proceed in like manner with the two others; the paper in the fourth square ought not to be discolored. The squares must not be moistened at once, because the first impure gas would in that case blacken them all.

Lime for the purpose of purifying coal-gas should be free from foreign matter. That which slackens the quickest, and produces the greatest heat during the operation, is the best. When dissolved in diluted muriatic acid it should not effervesce, and when perfectly pure should leave no insoluble residue.

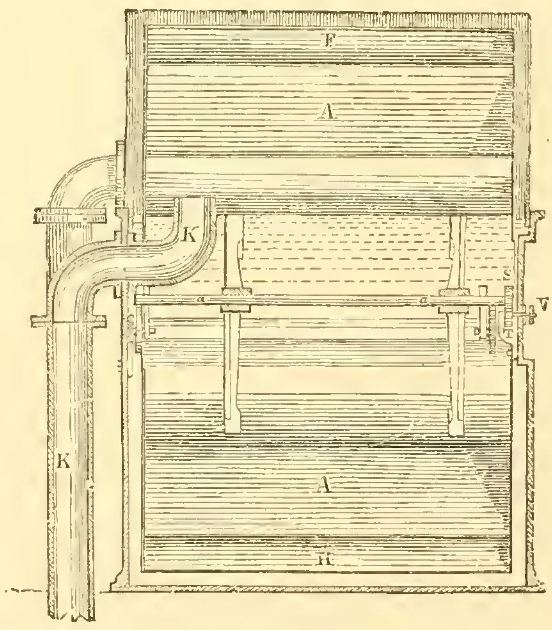
The Station-Meter.—The gas, after passing through the purifier, next enters the station-meter, the object of which is to measure the quantity of gas made per ton. The difference between the indications of the consumer's meter and the station-meter will indicate the loss of gas by leakage. The difference between the station-meter and the (wet) meter of the consumer is more of size than anything else, so that a description of one or the other will apply in both cases.

Fig. 1982 is a front elevation in section, and Fig. 1983 is a side elevation, also in section, of a station-meter of the capacity of 200 cubic feet, by which 300,000 cubic feet of gas may be measured and registered in 24 hours. The principal part of the machine consists of a hollow drum of thin

1982.



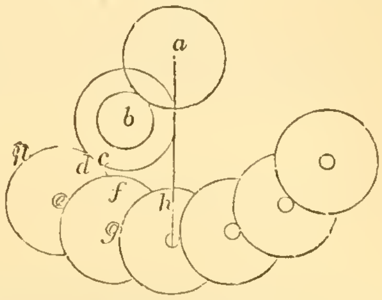

1983.




sheet-iron $A$ $A$, revolving upon an axis $a$, and divided into compartments, so arranged that, as the gas enters, it shall in revolving successively fill all the chambers, pass through them, and be discharged measured. The part of the drum which contains the gas is in the form of a concentric ring 1 foot 6 inches broad, 6 feet deep, and 7 feet 6 inches in extreme diameter, which will be understood by reference to the engraving. The plates which form the sides are of the same outer diameter as the drum, viz., 7 feet 6 inches, but are 2 feet 9 inches broad; they will therefore project within the smaller diameter, leaving the centre circle (through which the inlet-pipe $K$ passes) 2 feet in diameter. The surface of the water contained in the drum and outside tank of the meter is 4 inches above the upper circumference of this centre circle, when the drum is in its place; so that the communication between the outside and inside of the drum is cut off by a head of water of that height, and continues to be so in every part of the revolution. It is evident, therefore, that the gas must enter any chamber having its inner hood above the surface of the water. $B$ $C$ $D$ $E$ represent the inner hoods, and the direction of the gas from the inlet-pipe is shown by the small arrow at $B$. As the chamber fills with gas, it displaces the water, and causes the drum to revolve. Before $B$ dips into the water, the hood $C$ rises above the surface, and opens a communication for the gas into

its chamber; and so on with $D\ E$, when it will have completed one revolution and measured 200 cubic feet. The same action that allows the free passage of the gas *into* the chambers causes it to be expelled *from* them through the outer hoods $F\ G\ H\ I$, in the direction of the arrow at $F$: each of these outer hoods is sealed alternately in the same manner as the inner hoods, and opened for the passage of the gas from them, by one constantly being above the water-line. The direction in which the drum revolves is marked by the arrow over the top of the case. The bevels of the division-plates $d\ d$ are arranged so that they will enter the water without effort. The axis $a\ a$ on which the drum revolves is supported on friction-rollers; on the front end of this axis a spur-wheel $S$ is fixed, working into another wheel $T$, having half the number of teeth; at every half revolution of the drum it will therefore make an entire revolution; its spindle passes through a stuffing-box, and is furnished at the opposite end with another wheel $V$, which marks 100 feet on the index. From a pinion on the spindle of this last wheel another wheel is worked, having ten times the number of teeth on the pinion, which will therefore mark thousands. This last wheel is again furnished with a pinion and works into a third wheel, which will mark tens of thousands, and so on; the quantities marked on the dials increasing in a tenfold ratio up to hundreds of millions, or higher if thought necessary.

1984.



The entire train of wheel-work is shown in Fig. 1984, where $a$ is the first spur-wheel, working upon the main axis; $b$, the second wheel, both being inside the meter-case; $c$, the wheel on the opposite end of the shaft of $b$, which projects through a stuffing-box on the case, in order to communicate motion to the train of wheel-work, which must of course be on the outside of the meter-case; $d$, the wheel driving the hand which marks hundreds on the index, and having 100 teeth ($c$ has likewise the same number of teeth); $e$, the pinion on the wheel $d$, having 10 teeth; $f$, the wheel driving the hand which marks thousands on the index, having 100 teeth, and driven by the pinion $e$; $g$, the pinion of the wheel $f$ driving $h$, which marks tens of thousands on the index; and in like manner any quantity may be registered. If it be required to register units (and in smaller meters it is useful), the first wheel $d$ is made to drive a pinion $p$, having 10 teeth, to the spindle of which the hand marking units is attached.

The Holder, or Gasometer, serves not only for the storage of the gas, but to cause sufficient pressure for its distribution through the mains. Gas-holders are of two kinds: the single lift, and the double lift, or telescopic. The latter require counterpoises, which the simpler form do not, and are more expensive, but are very extensively used by all large works, especially where ground is valuable. The simple gasometer consists of an iron vessel, open at the bottom and inverted into a tank of water below the surface of the ground, having perfect freedom to rise and fall, and guided by upright rods fixed at several points in the circumference. The holder is so counterbalanced as not to exert a pressure on the gas more than equivalent to a column of water 6 inches high, this pressure being sufficient to force the gas through the mains to the consumers. The diameter and number of the vessels will vary according to the magnitude of the works to which they are attached and the space to be occupied by them.

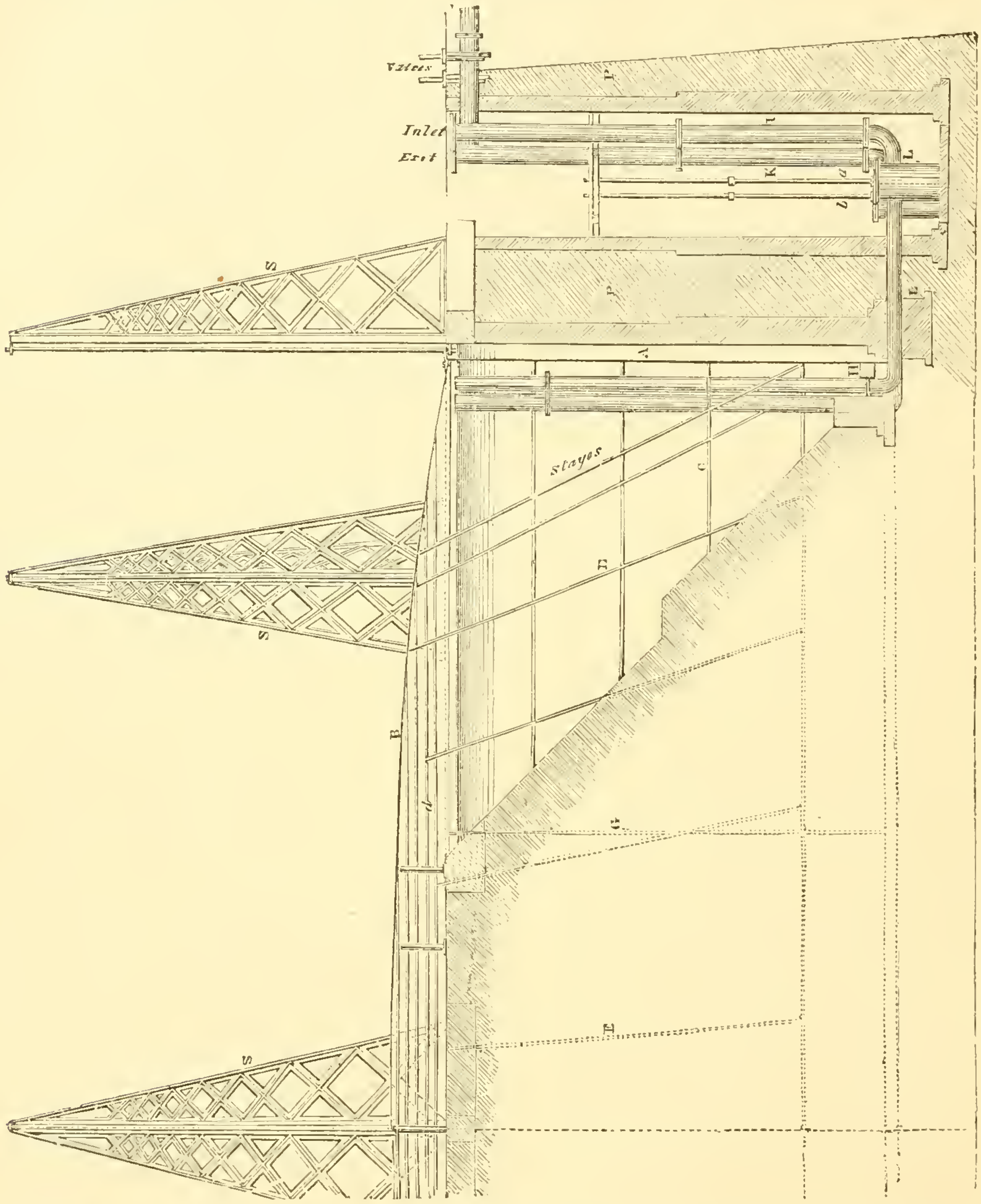
Fig. 1985 represents the half section of a simple gasometer, capable of containing 150,000 cubic feet, the diameter being 87 feet 6 inches, and the height 25 feet. The sides $A\ A$ are made of No. 16 iron plate (Birmingham wire-gauge), weighing $2\frac{1}{2}$ lbs. to the square foot, riveted together; the top $B$ of plate weighing about 3 lbs. to the square foot, or No. 14 gauge. $C\ C$, etc., are rings of 3-inch T-iron, placed 5 feet asunder, and riveted strongly to the sides; the rivets ought not to be more than 3 inches apart. The top and sides are secured together by 3-inch angle-iron, rolled to fit the curve. $d\ d$ are rings of bar-iron, about half an inch thick and 3 inches deep, fastened to the top by clips, which are riveted; these rings are placed about 6 feet apart, and strengthened further by diagonal bars, from one to another, breaking joint. $E$ are stays formed of wrought-iron pipe, about $1\frac{1}{2}$ inch diameter, fixed in the situations represented, their ends being bolted to the T-iron at the sides, and the rings on the top. $G$ are vertical rods, fixed at the upper and lower ends to the brickwork of the tank, and passed through eyes fast to the bottom of the side of the gasometer, serving to guide the vessel in its rise; their positions are between the standards $S$, on which are also guide-rods acting in like manner. The eyes serve as stops to prevent the vessel rising out of the water. The standards $S$, 8 in number, are each formed of 3 cast-iron frames 6 feet broad at their bases, of the same height as the gasometer, and jointed together in the form of a T on the plan; they are secured to the stone plinth by dovetailed lock-nuts, keyed and leaded. $H$ is the wooden curb, which ought always to be attached to a gasometer; its use is to regulate the flow of gas from one gasometer to another. While immersed in the water of the tank it acts as a float, and to some extent buoys up the vessel; when the gasometer has risen to its full height, it acts as a weight, being partly out of the water, thus causing the gas to flow into another gasometer not yet full, and which, having its curb completely immersed, is under less pressure. $I$ is the inlet-pipe, of the same diameter as that leading from the retorts, viz., 8 inches. Its mouth above the water-line should be rather higher than the edge of the tank. $K$ is the outlet-pipe, 12 inches in diameter, entering the gasometer under the same circumstances as the inlet-pipe. $L$ are receivers in which the tar or water collects from the mains, being pumped out by a small hand-pump, of which $a$ and $b$ represent the suction-pipes. $P$, masonry or brickwork.

A gasometer 100 feet in diameter and 39 feet high at the sides, containing 300,000 cubic feet, weighs about 116 tons 14 cwt. 36 lbs. A gasometer 36 feet in diameter and 12 feet deep contains 12,200 cubic feet, and weighs about 5 tons 2 cwt. 49 lbs.

Fig. 1986 represents an improved gasometer. The largest holder in the world is in London; it is

230 feet in diameter, and holds 3,000,000 cubic feet of gas. The largest holder in this country belongs to the New York Gas-Light Company; it is 168 feet in diameter, is supported by 16 columns 72 feet high, and stands 70 feet high when full. Its capacity is 1,500,000 cubic feet.

1985.




THE GOVERNOR, OR PRESSURE REGULATOR, causes the delivery of the gas through the mains at a constant pressure. An improved governor has been devised by Messrs. Braddock, of Oldham, England, which for safety has two counterbalance weights, and reverses the position of the inlet, which delivers the gas on the top of instead of beneath the cone, as in other governors. The cone is suspended to a bell by the same rod which passes through the central pipe; there is also another small pipe in connection with the outer part of the bell. The chamber within the bell having the same area as the cone, the pressure is always counterbalanced, and oscillation is prevented.

1986.

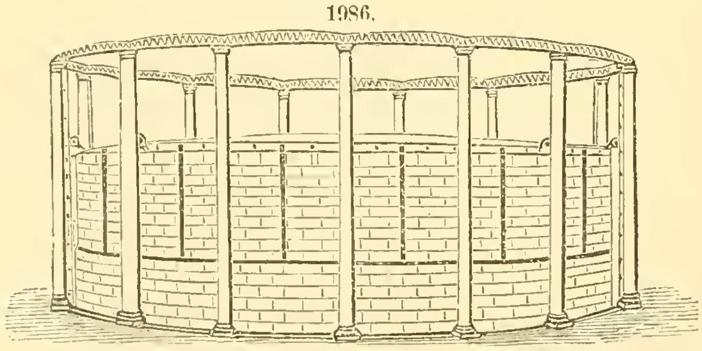
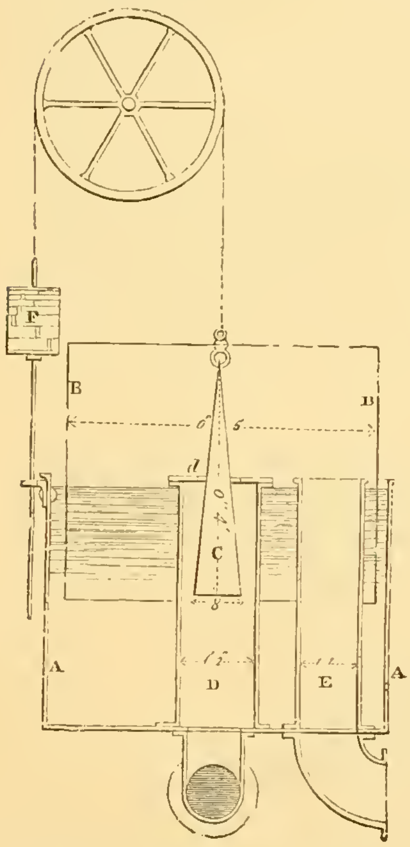


Fig. 1987 is an elevation, in section, and Fig. 1988 a plan, of a governor capable of equalizing the flow of 300,000 cubic feet of gas in 24 hours. *A A* is a cast-iron tank containing water, 5 feet 4 inches in diameter and 4 feet 6 inches

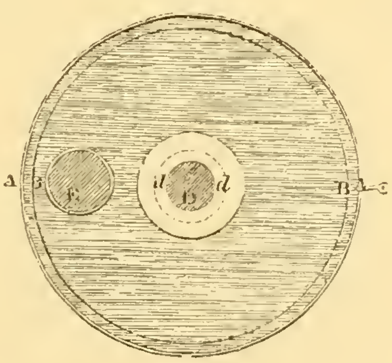
deep, in which the regulating vessel *B B* floats. *C* is a cone of cast-iron, turned true in the lathe, and suspended by an eye-bolt to the top of the floating vessel. *D* is the inlet-pipe, having a plate *d* on the top, furnished with an aperture, bored out to fit the diameter of the cone at the base, and which, if raised to that height, will completely shut off the gas from entering the vessel. *E* is the outlet-pipe, its diameter being regulated by the distance to which it has to convey the gas to the equilibrium-cylinder of the street-mains.

The floating vessel *B*, when immersed in water, of course loses a portion of its weight equal to that of the water which it displaces; and the density of gas contained in it will vary as the immersion. By making the chain *F* of a proper weight, it may be made to answer the purpose of a regulator of the pressure. Let it be supposed, for example, that the vessel weighs 1,000 lbs., and loses 100 lbs. of that weight when immersed in the water, and that a portion of the chain equal in length to the height which the vessel rises weighs 50 lbs., and the counterbalance 950 lbs. Then, when the vessel is immersed, its effective weight is 900 lbs., to which must be added the portion of chain now acting, as increasing the weight of the vessel, 50 lbs. The sum corresponds with the actual weight of the counterbalance, 950 lbs. Again, let the vessel be elevated out of the water; its actual and effective weight then is 1,000 lbs.; to balance which are opposed the counterpoise, 950 lbs., and the portion of the chain now removed to the other side of the pulley to counterpoise, and acting with it, 50 lbs. The sum corresponds with the actual weight of the vessel, 1,000 lbs. The effects of the vessel and counterpoise being thus opposed to each other, the pressure of the gas contained

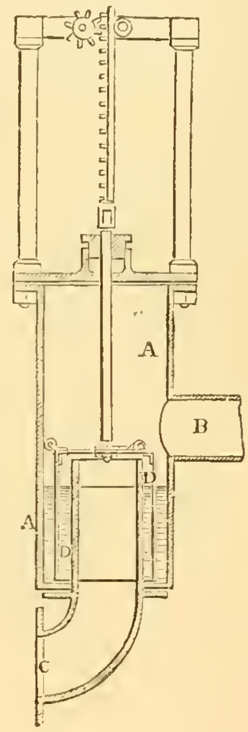
1987.




1988.




1989.




therein is equalized. By adding or removing the weight of the counterbalance, an increase or decrease of pressure may be effected.

The action of the governor is as follows: The outlet-pipe is connected with the mains, and the inlet-pipe with the gasometer supplying gas into the machine. It will be evident that, if the density of the gas in the inlet-pipe becomes by any means increased, a greater quantity of gas must pass between the sides of the adjusting cone and the aperture in the plate *d*, the consequence of which will be that the floating vessel will rise, and therefore contract the area of the opening in *d;* and if, on the contrary, the gas in the inlet-pipe decreases in density, the vessel will descend; so that, whatever density the gas may at any time assume in the gasometers or mains, its pressure in the floating vessel will remain uniform, and consequently the velocity of the gas passing into the mains will be regular: for when the aperture of the plate *d* would admit more gas than necessary for the supply to the mains, the floating vessel rises and diminishes the area of the inlet-pipe; and when, on the contrary, the inlet does not allow a sufficient quantity of gas to come from the gasometers, the gas passes out of the governor.

*Pressure Indicator.*—If a governor be not used, it is advisable to have a *pressure indicator* attached to the main or mains that leave the works, to serve as a check upon the conduct of the workmen whose duty it is to regulate the pressure of gas in them according to the demand at certain hours of the night. It is thus constructed: A small gasometer about 12 inches in diameter is made to move in a tank of water in such a manner that it shall rise or fall according to the pressure in the mains, with which it is connected by a small pipe; a guide-rod, furnished on the top with a pencil, marks the exact amount of pressure upon a sheet of paper coiled round a cylinder. This cylinder is moved

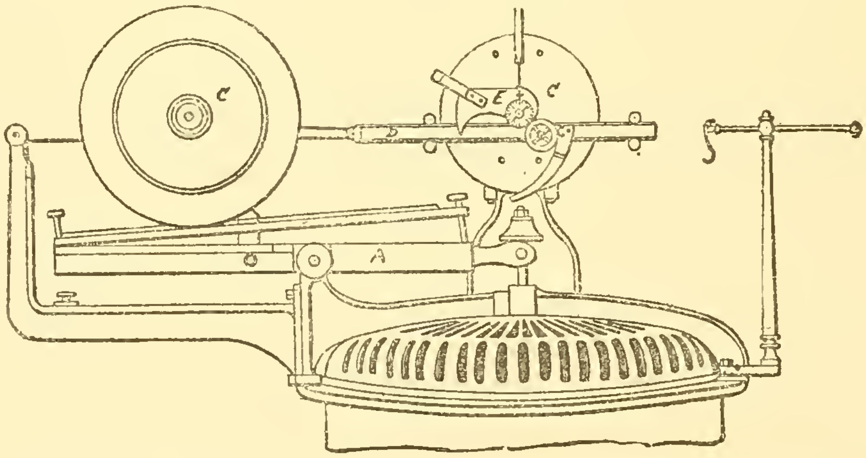
round once in 12 hours by a timepiece. It is evident, therefore, that if the paper be divided by horizontal lines corresponding to the rise or fall of the gasometer by every tenth of an inch increase or decrease of the pressure, and if it be divided by vertical lines corresponding to the revolutions of the timepiece in 12 hours, it will effect the object required. The gasometer must be formed with an air-vessel inside, so that when it is totally immersed it shall be in exact equilibrium with the external atmosphere, and when risen to its full height it shall have a pressure equal to that required to force the gas through the mains. Say the height to which the gasometer rises is equal to 10 inches, and the pressure required is 3 inches; then if the paper be divided into 30 parts by horizontal lines, each division will indicate one-tenth of an inch.

Pressure-gauges, as the name implies, are instruments by which the velocity with which the gas flows into the main is ascertained. They are made of glass tubes partially filled with colored water, and furnished with graduated scales divided into inches and tenths from a point in the centre of the scale marked zero. When no gas is passing into the main to which one of these instruments is attached, the columns of water contained in the tubes are in equilibrium with the external air, and stand at 0. When the gas is admitted, the equilibrium is destroyed; the gas depresses one column and raises the other, the total variation being the amount of pressure.

Fig. 1989 shows a section of a water-valve. It is formed of an air-tight cylinder *A A*, containing a portion of tar or water. *B* is the inlet-pipe, which communicates with the gasometer. *C* is the outlet-pipe, which conveys the gas to the main. *D D* is an inverted cup, 10 inches deep, furnished with a rod passing through a stuffing-box, by which it is raised or lowered. When the cup is in the situation shown in the figure, it is evident that the communication between the outlet and inlet pipes is shut off by the pressure of a column of water 10 inches high. When the cup is raised above the mouth of the outlet-pipe by the rack and pinion, a free passage is left for the gas. This description of valve may be fixed with advantage between the gas-holders and the mains, or between any system of lime-water purifiers.

*Isabell's Automatic Governor*, for regulating the pressure of gas in street mains, is shown in Fig. 1990. The distinguishing feature of this governor consists in automatically changing the position of the weights to operate the valve and make the desired variations in pressure, as opposed to putting on and taking off weights by hand of an attendant. The operation of this governor is as follows: At the inner end of the lever *A* is suspended a rod which carries a perfectly balanced valve, which works easily in a proper chamber, located in the outlet-pipe holder. At the outer end of the lever *A* is pivoted an adjustable bar or track *B*, on which are placed the rolling weights *C*. These

1990.




weights are connected by a cord to a sliding bar *D*, working between friction-rollers, and driven by a cam *E* on the main spindle of a powerful clock, contained in the case *G*. As the weights are moved in at the proper time by the action of the clock and cam, the valve below is opened and the pressure gradually increased to the desired point, and held there until the time set for it to be diminished by the rolling back of the weights and the consequent gradual closing of the valve. The cam *E* is easily and quickly secured in any position on the spindle, and has stamped upon it the hours of the day, as shown by the index. It will be at once apparent how any desired effect can be obtained by changing the position of the cam, or by putting on cams of different proportions.

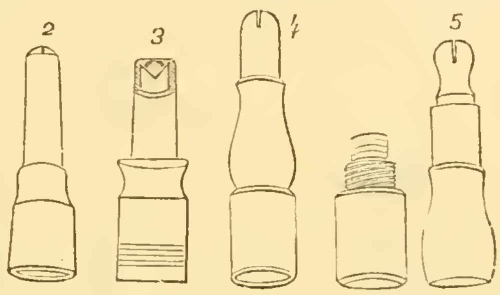
*Works for Reference.*—"Treatise on the Manufacture of Coal-Gas," Richards, London, 1877; "A Treatise on the Science and Practice, on the Manufacture and Distribution of Coal-Gas," Muspratt's "Chemistry;" Muspratt's "Handbuch der Technische Chemie," 3d ed., 1875; Bolley's "Handbuch der chem. Technologie," 1862; Wurtz's "Dictionnaire de Chimie," and "Neues Handwörterbuch der Chemie;" "Le Gaz;" Knapp's "Lehrbuch der chem. Technologie," 3d ed., 1865; Wagner's "Jahresbericht der chemischen Technologie;" Schilling, "Traité d'Eclairage par le Gaz;" Matthews's "History of Gas-Lighting," 2d ed., 1832; Schilling, "Handbuch für Steinkohlengas;" Blochmann's "Beiträge zur Geschichte der Gasbeleuchtung," 1871; Wilkins, "How to Manage Gas;" Sugg, "Gas Manipulations, with a Description of the various Instruments and Apparatus employed in the Analysis of Coal and Coal-Gas;" English "Abridgments of Specifications of Patents relating to the Production and Applications of Gas," 1860; Richards, "Gas-Consumer's Guide;" Accum's "Practical Treatise on Gaslight," 4th ed., 1818, and "Description of the Process of Manufacturing Coal-Gas," 1819; D'Hurcourt, "De l'Eclairage du Gaz;" Bowditch, "The Analysis, Technical Valuation, Purification, and Use of Coal-Gas;" Thomas Newbigging, "The Gas-Manager's

Hand-Book;" Mason, "Gas-Fitter's Guide;" Bower, "Gas Engineer's Book of Reference;" Hughes, "Gas-Works and Manufacturing Coal-Gas;" Clegg, "On the Manufacture of Coal-Gas;" Colburn, "The Gas-Works of London," and "Gas-Consumer's Guide." H. A. M., Jr.

GAS, ILLUMINATING, BURNERS FOR. There are three conditions necessary for the production of a perfect burner—that is, one that is "perfectly adapted to the quality of the gas which it is destined to consume, and which will develop, when burning a regulated quantity, the maximum of light possible: 1. The gas should issue from the burner at as low a pressure as is possible consistent with the proper flow of gas. 2. The air-supply should be suitably regulated, the amount of atmospheric oxygen supplied to the flame being exactly proportioned to the richness of the gas. 3. The burner should be so constructed that the gas is kept as cool as possible up to the point of its being consumed."

Since the experiments of Christison and Turner in 1825, it has been frequently maintained that gas gives a larger proportion of light when it is burned in large quantities than in small; in other words, that the larger the quantity of gas consumed in any kind of burner, the larger will be the proportion of light obtained from the gas. Properly conducted investigations made by the Referees of the London Gas Companies have demonstrated the fallacy of the above doctrine, and have proved that the observed variations in the illuminating power of gas upon which the conclusion was based are entirely due to the burners. The correct statement of the matter is, that with every burner there is a certain point of gas consumption at which the burner gives *its* maximum of light, and that, if the consumption be either increased or diminished from that point, the proportion of light obtained from the gas will be reduced. At the same time, even taking each kind of gas-burner at its best, the difference in the quality of the gas-burners in general use is so great, that some of them yield only one-fourth or one-fifth the light obtainable from burners of the best construction. The chief point to be observed, alike in the construction and in the employment of burners, is the due regulation of the air-supply to the flame. This depends partly on the size and shape of the gas-flame—for, of course, the larger the surface of the flame, the more is it brought in contact with the air—but still more upon the draught, whereby the same extent of surface will be more or less exposed to the action of the air.

1991.

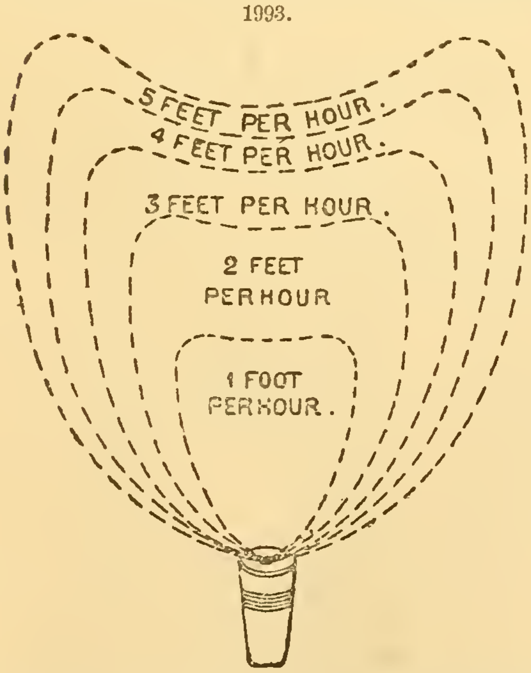



1992.

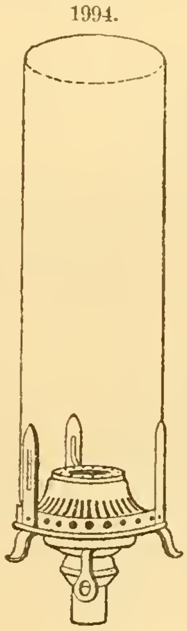
There are three kinds of burners in use: the bat-wing burner, with a slit; the fish-tail burner, with two oblique holes in the end facing each other; the argand burner, a circular burner with a ring of small holes, and provided with a gas-chimney and interior supply of air. Burners are made of brass, iron, or lava (soapstone); the last is far preferable, from the fact that the holes or slits are not liable to be stopped up by rust.

The *bat-wing burner*, represented at 2, 4, and 5, Fig. 1991, is so called on account of the flame taking the form of the wing of a bat. The burner consists of a metal, lava, or adamas nib, with a hole pierced therein within a short distance of the top, across which is a slit from which the gas

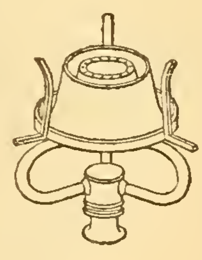
1993.




1994.




1995.



issues in a thin flame. The bat-wing burner is best adapted for all out-door lights. The slit may be freed from any obstruction by passing a thin card through the same. The flame is too broad to be used in globes or shades.

The *fish-tail burner* received its name from the shape of the flame. It is formed of the same

materials as the bat-wing burner, but differs from the latter by the hole, which is bored nearly to the top, receiving two orifices or small holes, drilled at such an angle that each jet of gas, in issuing, impinges against the other, forming when lighted a sheet of flame at right angles with the holes. Figs. 1992 and 1993 represent such a burner.

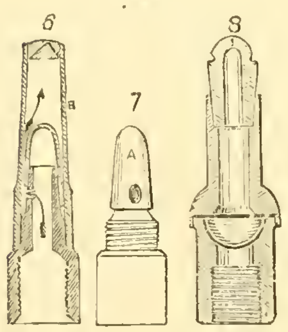
The *argand burner* is represented by Figs. 1994 and 1995, and has been already described.

The argand burner is best adapted for ordinary gas; it gives a very steady flame, and consumes the gas to the best advantage. It is provided with a cut-off or check of very simple construction. The best burner yet constructed is Sugg's London burner, shown in Fig. 1995 without its chimney. For general use 5- or 6-foot lava-tipped check bat-wings are the most economical.

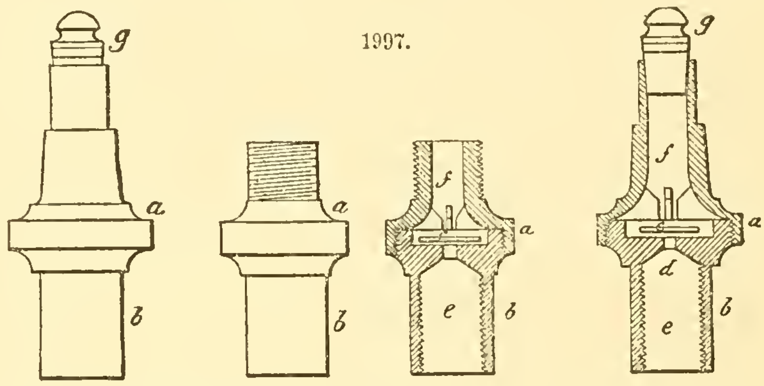
The pressure of the gas is one of the most important considerations. Argands give most light under a pressure of one-tenth of an inch, bat-wings and fish-tails under a pressure of three-tenths or four-tenths of an inch. As gas is supplied to consumers under pressures varying from 3 or 4 inches down to one-tenth of an inch, it is very desirable to check the flow of gas when it is excessive. Hence regulating burners and regulators for checking the flow of gas have been invented. A very simple method for checking the flow of gas is to screw a 5- or 6-foot burner over a 3- or 4-foot burner.

*The Plass Economic Gas-governing Burner*, Figs. 1996 and 1997, may be described as follows: It consists of a case or shell constructed usually in two parts, *a* and *b*, with a flexible automatic disk-valve *c*. An increase of pressure, whether it occurs in the gas-mains or service-pipes, is instantly communicated to the valve *c*, which rests upon and contracts the aperture *d* through which the gas enters from the inlet *e* into the chamber *f*, and, in consequence of the relation which pressure bears to volume or quantity, the quantity of gas now admitted in a given time is exactly equal to that which passed when the pressure was less and the opening greater. From the chamber *f* the gas passes through the outlets at the lava tip *g* in the upper shell *a*, resulting in a rich, clear flame.

1996.



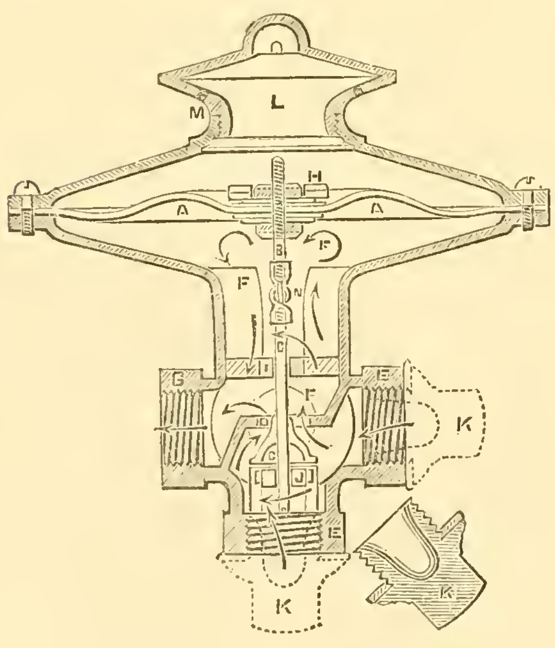
1997.



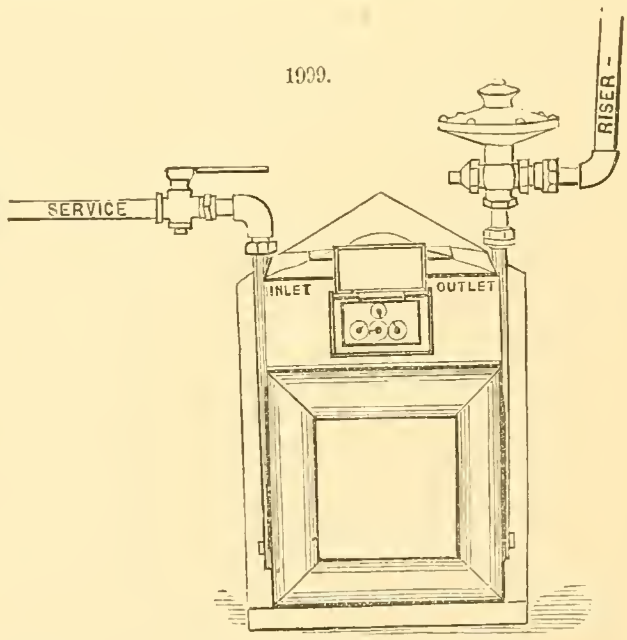
When the pressure in the mains or house diminishes, the valve *c* slightly rises; and the aperture *d* to the chamber *f* is again enlarged, admitting of a sufficient volume of gas to correspond with the now reduced pressure.

*The* Plass gas-governor, shown in Fig. 1998, is constructed on the same principle as the burner just described. Fig. 1999 shows the governor properly connected with the meter.

1998.



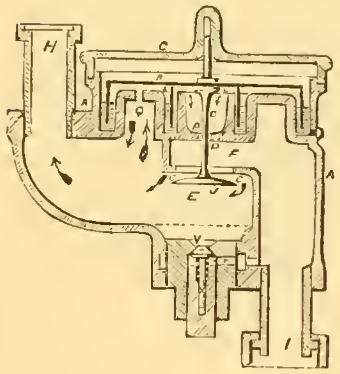
1999.



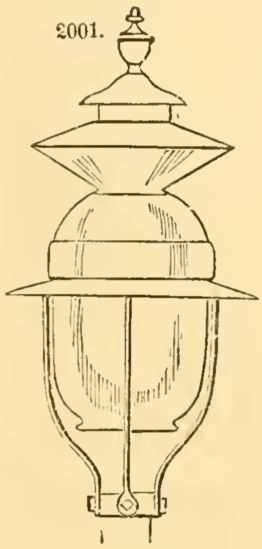

*The Champion Gas-saving Regulator* is shown in Fig. 2000. The following is a description of the same: *A*, outer case of cast-iron; *B*, large inverted cup; *C*, cast-iron cap; *D*, brass valve-rod; *E*, discharge-chamber; *F*, inlet-chamber; *G*, valve-seat; *H*, brass coupling connecting regulator with house-pipe; *I*, brass coupling connecting regulator with meter; *J*, brass valve; *L*, small inverted

cup; *P*, opening for valve-rod through which the gas flows into and under cup *L*; *Q*, passage for gas to large inverted cup *B*; *V*, valve-seat to automatic discharge; *W*, brass valve; *X*, valve-rod; *Y*, passage from regulator to inlet-chamber. The gas flows from the meter into the inlet *I* through the opening *P* up and under the small inverted cup *L*, which cup is sealed and made to float in quicksilver, and is attached to the valve-rod *D*. This cup is made to rise and fall according to the increase or decrease of the gas-pressure. When the gas-pressure is greatest, the aperture controlled

2000.



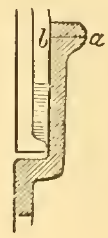
2001.



2002.

2003.

2004.



by the valve *J* is made less by the upward movement of the valve. The regulated gas then flows into the discharge-chamber *E*, and a portion of it ascends into and under the large inverted cup *B*, which is also sealed and made to float in quicksilver, and is also attached to the valve-rod *D*. This large cup gives a larger area to the buoyant power, and prevents irregularity in the movement of the valve. The cups are weighted and adjusted according to the light that may be required. If any condensation should ever be collected in the regulator, it is automatically discharged by means of the valve *W* through the passage *Y* to the meter.

For economy's sake, if for no other reason, there should be a governor attached to every meter.

A good street-lamp is shown in Fig. 2001, every practical device being employed to get the full benefit of the light. It may be described as follows: The glass shade is oval in shape, with the lower part open; the glass itself is very thick and strong, but the principal improvement is the use of two porcelain reflectors, the one on the lower part of the chimney, the other at the centre of the glass shade or bell, which succeed in throwing down on the pavement considerably more light than do the street-lamps ordinarily used. Both these reflectors are outside the shade, and thus escape being blackened by the smoke. The upper one radiates light to a distance, but always downward; the lower one sends the rays down near the lamp all round, and prevents any shadow being cast. In a band round the upper part of the lamp, above the lower reflector, the names of the streets are lettered on ground glass. H. A. M., Jr.

GAS, ILLUMINATING, DISTRIBUTION OF. *Mains.*—The term "main" is applied to all cast-iron conduit-pipes that serve to convey gas from the works to the place or district to be lighted, and especially applied to those pipes from which smaller ramifications branch. The diameters of the mains vary from 1½ inch to 15 or 18 inches, according to the quantity of gas required to be supplied, and the distance it has to flow.

The 1½-inch mains are cast 4 feet 6 inches long, the 2- and 3-inch mains about 6 feet long, and all the other sizes 9 feet, with a socket at one end and a plain bead at the other.

*Sockets.*—Figs. 2002, 2003, and 2004 represent the sections of sockets of different-sized pipes, to a scale of 1½ inch to the foot. Fig. 2004 is that of mains from 9 to 15 and 18 inches in diameter. The usual thickness of metal is shown by the hatched lines, and is proved to be sufficient. The *depth* of these sockets is 4½ inches.

Fig. 2003 is a section of the sockets of mains from 4 to 8 inches in diameter; their depth 4 inches.

Fig. 2002 is the thickness of those of a smaller diameter, 3 inches deep.

The thickness of the main pipes ought to be as follows:

| | | | |
|---|---|---|---|
| 1½ inch diameter........... | ¼ inch thick. | 9 inches diameter...... ..... | ½ inch thick. |
| 2 inches " ............ | ¼ " " | 10 " " ............ | ½ " full. |
| 3 " " ............ | ¼ " full. | 12 " " .... ...... | ⅝ " " |
| 4 " " ............ | ⅜ " " | 13 " " ... ....... | ⅝ " " |
| 5 " " ........... | ⅜ " " | 14 " " ........... | ¾ " " |
| 6 " " ............ | ⅜ " " | 15 " " ........... | ¾ " " |
| 8 " " ............ | ½ " " | 18 " " ........... | ⅞ " " |

The annular space left between the bead end of one and socket of the next pipe should be about half an inch in the large mains, and not less than three-eighths in the small.

*Joints.*—To make the joints, spun yarn is driven before the pipes to within 2½ inches of the lip of the socket, and a good fitting of the two pipes being effected, melted lead is poured into the remaining cavity, which when set is calked or hammered in with a blunt square-pointed chisel.

59

In order to guard against the danger of water remaining that enters from the external surface into the pipes, and the deposition of other condensed matter, a reservoir should always be placed at the lowest point, where two or more descending mains meet and form an angle, to receive the water, etc., that may happen to collect at this angular point, an accumulation of which would obstruct the passage of the gas through the mains. These receivers ought to be at least twice the diameter of the mains between which they are interposed, and four times that diameter in depth. These receivers afford the best indication of the sound or leaky state of the system of mains. In all instances where the pipes are perfectly sound, observation has shown that half a mile of gas-mains, three inches in diameter, does not deposit more than a quart of condensed vapor or water in the year; on the other hand, when the mains are leaky, the water of the reservoir requires to be pumped out, particularly in wet weather, as frequently as once a fortnight. The loss of gas by such leakage is much greater than is generally imagined. In order to keep the common air out of the faulty mains, a constant influx of gas is often necessary; this is of course so much gas lost to the economy of the establishment.

*Distribution of gas through mains.*—The velocities of different gases under the same pressure will be to one another, inversely, as the square roots of their specific gravities; therefore a heavy gas will be discharged through the same opening with a less velocity than that due to a lighter gas. For example, if coal gas of the specific gravity ·420, and with a pressure of five-tenths of an inch, flows through a circular orifice one-fourth of an inch in diameter, at the rate of eighty cubic feet per hour, gas having the specific gravity ·400 will flow through the same opening at the rate of 81·9 per hour, pressure remaining the same. For by inverse proportion,

As $\sqrt{400} = 20{\cdot}000$
Is to 80, the quantity discharged of the heavy gas,
So is $\sqrt{420} = 20{\cdot}493$
To 81·9, the quantity of lighter gas discharged.

The discharges of the same gas through different openings and under the same pressure, are proportional to the areas of the orifices in circular inches, or to the squares of their diameters. Allowing an excess in the larger openings for the difference of the friction, the results of the annexed experiments will agree very nearly with this law.

| Diameter of orifice in inches and parts. | Quantities of gas discharged in cubic feet per hour. Pressure = 5-10ths. By experiment. | By calculation. |
|---|---|---|
| ·25 | 80 | |
| ·50 | 321 | 320 |
| ·75 | 723 | 720 |
| 1·00 | 1287 | 1280 |
| 1·125 | 1625 | 1620 |
| 1·25 | 2010 | 2000 |
| 1·50 | 2885 | 2880 |
| 6·00 | 46150 | 46080 |

To obtain the velocities of the same gas from any other opening, say,

As the square of given opening,
Is to the given quantity discharged,
So is the required opening
To the required quantity discharged.

The quantities of the same gas discharged in equal times by a horizontal pipe under the same pressure and for different lengths, are to one another in the inverse ratio of the square roots of the lengths. Hence, when we know the quantity of gas discharged from a given length of pipe, we may find the quantity discharged by any other length with any pressure, and of gas of any specific gravity.

*Example of the foregoing rule.*—It is required to find the number of cubic feet that will be discharged from a horizontal pipe six inches diameter and 1760 yards long, the specific gravity of the gas being ·420, and the pressure equal to five-tenths of an inch perpendicular head of water. We know by experiment that 44,280 cubic feet will be discharged by a six-inch pipe 3·46 yards long; therefore, by inverse proportion, say,

As $\sqrt{1760} = 41{\cdot}952$, the required length,
Is to 44,280, the known quantity discharged,
So is $\sqrt{3{\cdot}46} = 1{\cdot}860$, the known length,
To 1963·2, the required quantity discharged.

We therefore find that the loss by friction in a pipe a mile long is 44,116·8, the initial velocity being equal to 46,080 by calculation.

A horizontal main, 16 inches diameter and 1760 yards long, is laid from the works to the equilibrium cylinder: it is required to know how many cubic feet of gas of the specific gravity ·390 will be discharged with a pressure equal to a head of water of 6-10ths of an inch.

We have found by the last example that a six-inch pipe, one mile long, with a pressure of 5-10ths of an inch, will deliver 1963 cubic feet of gas having the specific gravity ·420, in one hour. Then say, as 36, the square of the diameter of the six-inch pipe, is to 1963, the quantity of gas delivered, so is 256, the square of the diameter of the sixteen-inch pipe, to 13,959, the required quantity delivered by a sixteen-inch, one mile long. For the difference of specific gravity, say,

As $\sqrt{\cdot 390} = \cdot 197$, the specific gravity of the lighter gas, is to 13,959, the quantity delivered of the specific gravity ·420, so is $\sqrt{\cdot 420} = \cdot 204$, the specific gravity of the heavy gas, to 14,455 = the quantity delivered of the specific gravity ·390.

And for the difference of pressure, say,

As $\sqrt{\cdot 50} = \cdot 707$, the first pressure, is to 14,455, the quantity discharged through a sixteen-inch pipe by that pressure, so is $\sqrt{\cdot 60} = \cdot 774$, the required pressure, to 15,824, the required quantity, of specific gravity ·390 discharged from a sixteen-inch pipe, with a pressure equal to 6-10ths of an inch head of water. The actual quantity discharged is about 16,500 cubic feet.

An accurate experiment was made by Mr. Clegg, at the Pancras Station, on the quantity of gas discharged through a four-inch main, six miles in length, with a pressure of three inches perpendicular head of water. The specific gravity of the gas was not taken until some hours after the experiment, when it was found to be ·398.

A new four-inch main had to be laid for the purpose of supplying parts of the parish of St. Marylebone with gas; after completing a circle of nearly six miles in circumference, it terminated within the distance of a short street from the point at which it left the works. By completing this distance, the two ends of the pipe were brought together on exactly the same level. There were no short bends, and all the services and branches were closed. The pipe measured exactly six miles in length. The leakage was ascertained in the first place by shutting the valve adapted to the returned end, and observing the gasometer; it was found to be thirty-three cubic feet at the end of one hour, and was allowed for. At the commencement of *another* hour the valve was opened and free passage given to the gas, which was allowed to escape: by observing the gasometer at the end of this hour, it was found that 885 cubic feet had been expended; deducting thirty-three cubic feet from this for the leakage, 852 will remain for the actual quantity discharged at the end of six miles. This experiment is valuable to the practical man, both for the unquestionable data it supplies, and for its close approximation to the rules here laid down.

The quantity discharged by calculation is............................ 873 cubic feet
By experiment ............................................................ 852 "

Difference.................. 21

TABLES *of the different quantities of coal gas of the specific gravity ·420, delivered in one hour, from horizontal pipes of different diameters and lengths, and under different pressures*

QUANTITIES DELIVERED BY A TWO-INCH MAIN IN CUBIC FEET.

| Length of pipe in yards. | Pressure in inches and parts. | | | Perpendicular head of water. | | |
|---|---|---|---|---|---|---|
| | 0·50 | 0·75 | 1·00 | 1·50 | 2·00 | 3·00 |
| 10 | 2896 | 3558 | 4135 | 4923 | 5792 | 6950 |
| 15 | 2364 | 2904 | 3331 | 4089 | 4728 | 5768 |
| 20 | 2047 | 2507 | 2886 | 3541 | 4094 | 4994 |
| 25 | 1830 | 2241 | 2580 | 3165 | 3660 | 4465 |
| 30 | 1673 | 2049 | 2368 | 2894 | 3346 | 4082 |
| 40 | 1445 | 1770 | 2037 | 2490 | 2890 | 3525 |
| 50 | 1294 | 1585 | 1824 | 2238 | 2588 | 3157 |
| 100 | 915 | 1121 | 1290 | 1582 | 1830 | 2232 |
| 150 | 748 | 916 | 1054 | 1304 | 1496 | 1825 |
| 200 | 647 | 792 | 912 | 1119 | 1294 | 1578 |
| 250 | 579 | 709 | 816 | 1010 | 1158 | 1412 |
| 300 | 522 | 639 | 736 | 903 | 1044 | 1273 |
| 400 | 457 | 559 | 644 | 790 | 914 | 1115 |
| 500 | 409 | 500 | 576 | 707 | 818 | 997 |

QUANTITIES DELIVERED BY A SIX-INCH MAIN IN CUBIC FEET.

| Length of pipe in yards. | Pressure in inches and parts. | | | Perpendicular head of water. | | |
|---|---|---|---|---|---|---|
| | 0·50 | 0·75 | 1·00 | 1·50 | 2·00 | 3·00 |
| 100 | 8242 | 10095 | 11657 | 14276 | 16484 | 20190 |
| 150 | 6730 | 8242 | 9517 | 11657 | 13460 | 16484 |
| 200 | 5828 | 7138 | 8242 | 10095 | 11657 | 14276 |
| 300 | 4759 | 5828 | 6730 | 8242 | 9517 | 11657 |
| 440 | 3929 | 4813 | 5557 | 6806 | 7858 | 9626 |
| 500 | 3686 | 4515 | 5213 | 6384 | 7372 | 9030 |
| 600 | 3365 | 4121 | 4759 | 5828 | 6730 | 8242 |
| 700 | 3115 | 3816 | 4406 | 5396 | 6230 | 7632 |
| 880 | 2778 | 3403 | 3929 | 4813 | 5557 | 6807 |
| 900 | 2747 | 3365 | 3886 | 4759 | 5494 | 6730 |
| 1000 | 2606 | 3192 | 3686 | 4515 | 5213 | 6384 |
| 1760 | 1965 | 2406 | 2778 | 3403 | 3929 | 4813 |
| 2640 | 1604 | 1965 | 2269 | 2778 | 3208 | 3929 |
| 3520 | 1389 | 1702 | 1965 | 2406 | 2778 | 3403 |
| 5280 | 1134 | 1389 | 1604 | 1965 | 2269 | 2778 |
| 7040 | 982 | 1149 | 1389 | 1702 | 1965 | 2298 |
| 8800 | 879 | 1076 | 1287 | 1521 | 1758 | 2152 |
| 10000 | 824 | 1010 | 1166 | 1428 | 1648 | 2019 |

QUANTITIES DELIVERED BY A TWELVE-INCH MAIN IN CUBIC FEET.

| Length of pipe in yards. | Pressure in inches and parts. | | | Perpendicular head of water. | | |
|---|---|---|---|---|---|---|
| | 0·50 | 0·75 | 1·00 | 1·50 | 2·00 | 3·00 |
| 100 | 32968 | 40380 | 46628 | 57104 | 65936 | 80760 |
| 150 | 26920 | 32968 | 38068 | 46628 | 53840 | 65936 |
| 200 | 23312 | 28552 | 32968 | 40380 | 46628 | 57104 |
| 300 | 19036 | 23312 | 26920 | 32968 | 38068 | 46628 |
| 440 | 15716 | 19252 | 22228 | 27224 | 31432 | 38504 |
| 500 | 14744 | 18060 | 20848 | 25536 | 29488 | 36120 |
| 600 | 13460 | 16484 | 19036 | 23312 | 26920 | 32968 |
| 700 | 12460 | 15264 | 17624 | 21584 | 24920 | 30528 |
| 880 | 11112 | 13612 | 15716 | 19252 | 22228 | 27224 |
| 900 | 10908 | 13460 | 15544 | 19036 | 21816 | 26920 |
| 1000 | 10424 | 12768 | 14744 | 18060 | 20848 | 25536 |
| 1760 | 7860 | 9624 | 11112 | 13612 | 15716 | 19252 |
| 2640 | 6416 | 7860 | 9076 | 11112 | 12832 | 15716 |
| 3520 | 5556 | 6808 | 7860 | 9624 | 11112 | 13612 |
| 5280 | 4536 | 5556 | 6416 | 7860 | 9076 | 11112 |
| 7040 | 3928 | 4596 | 5556 | 6808 | 7860 | 9624 |
| 8800 | 3516 | 4304 | 5148 | 6084 | 7032 | 8608 |
| 10000 | 3297 | 4038 | 4663 | 5710 | 6594 | 8076 |

In the foregoing Tables we have considered the mains as *horizontal.*

In mains rising *above* the horizontal line the quantity of gas delivered by them will be greater, and in mains falling *below* that line it will be less. In the first instance, the resistance offered to the flow of gas by the atmospheric pressure will be lessened, and in the latter it will be increased, and will cause a difference in the necessary pressure for the discharge of the gas of one-tenth of an inch head of water for every ten feet rise or fall.

The effect of bends and angles in the main, upon the quantity of gas delivered, is essentially a matter of experiment: they may be considered as so many mechanical obstructions. The results of the following experiments will show, in some measure, what allowance to make for quadrant, semicircular, and right-angle bends. A two-inch pipe thirty feet long, perfectly horizontal and free from obstructions, delivered 2898 cubic feet of gas in one hour, with a pressure of five-tenths of an inch head of water. The same pipe, disconnected in the middle of its length, and returned by a semicircular bend to the point at which it left the gasometer, delivered 2754 cubic feet in the same time, being a difference of nearly one-twentieth in the whole quantity. The semicircular bend was removed and a quadrant bend substituted, making the two fifteen-foot lengths of pipe form a right angle with one another; the quantity delivered was 2834 cubic feet in the hour, a difference of about 1-45th of the first discharge. Again, the pipes were disconnected, and a right-angle bend substituted for the quadrant; the quantity delivered in the hour was 2824, a difference of 1-39th of the first discharge.

*Services* are wrought-iron tubes, for the purpose of supplying the interior of houses with gas from the mains; every small tube on to which a burner is fixed, whether for public or private use, is called a *service.*

In order that the pipes for conveying the gas from the mains and distributing it through the houses or other buildings to be lighted, may in the first place be neither unnecessarily large or too small, the following rule is given:

One gas-lamp consuming four cubic feet in an hour, if situated forty feet from the main, requires a service not less than a quarter of an inch in the bore.

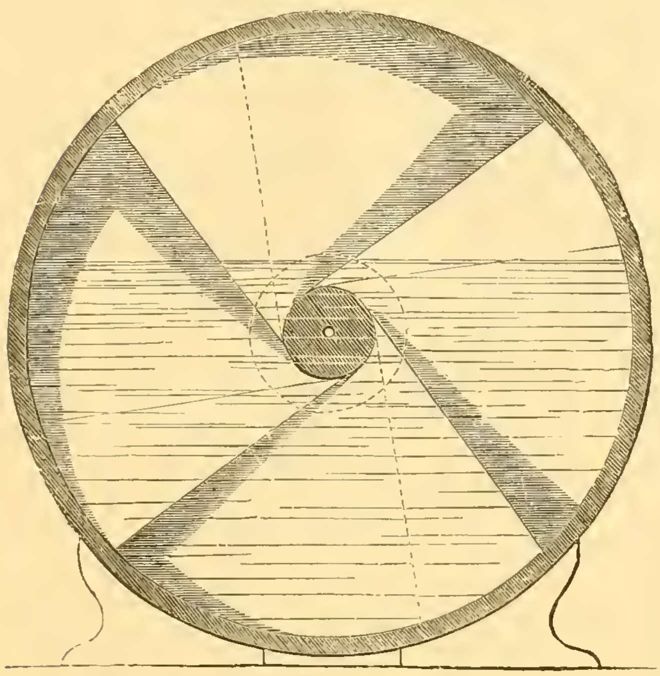
| | | | | |
|---|---|---|---|---|
| 2 lamps, ............ | 40 feet from the main, | require | | a three-eighth service. |
| 3 " ............ | 30 | " | " | a three-eighth tube. |
| 4 " ............ | 40 | " | " | a half-inch service. |
| 6 " ............ | 50 | " | " | a five-eighth service. |
| 10 " ............ | 100 | " | " | a three-quarter service. |
| 15 " ............ | 130 | " | " | an inch service. |
| 20 " ............ | 150 | " | " | a service $1\frac{1}{4}$ in diameter. |
| 25 " ............ | 180 | " | " | a $1\frac{3}{8}$ service. |
| 30 " ............ | 200 | " | " | a service $1\frac{1}{2}$ in diameter. |

It is desirable that all bends should be circular. No branch ought to proceed from a service of a quarter of an inch in the bore, and no more than two from a three-eighth service. All pipes, before they are fixed, must be proved by condensing air into them by means of a hand-syringe while under water; the leak will be easily detected by the air-bubbles which rise through the water. For conducting the gas from the street-mains into the interior of a house, or any building to be lighted, a wrought-iron pipe of sufficient diameter is tapped into the main, and carried in a straight line to the nearest wall of that building, through which it must pass; and on the inside be furnished with a good stop-cock. If all the fittings rise from the main no siphon is necessary, but if any part of them fall below the main a small receiver must be attached to the lowest point, fitted with a screw-plug at the bottom, so that any moisture may be drawn off. The pipes which convey the gas to the burners

must be in as direct a line as possible, to avoid unnecessary expense and obstructions. The union joints used to connect two services together must be of the same diameter as the pipes, and soldered firmly on to them.

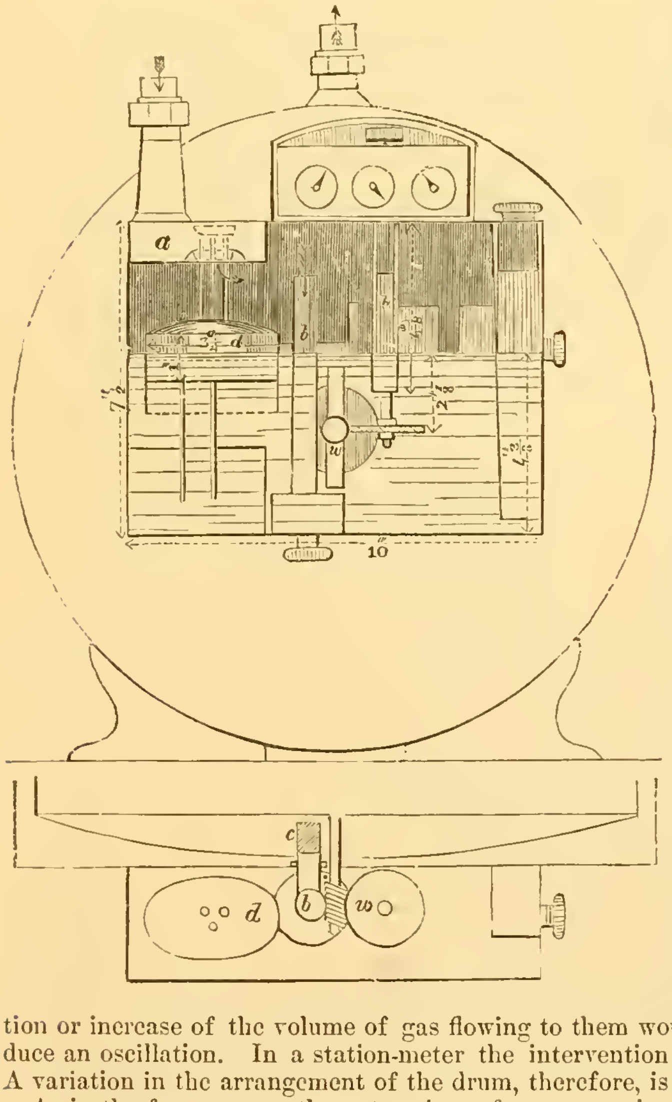
Gas-fittings ought to be made of the best materials; they should be judiciously arranged, and fixed by skillful workmen. The choice of a situation for the main cock is of importance; it should be placed as near as possible to the inside of the wall through which the gas is admitted from the street-main, and where it will at all times be accessible to the inmates of the house. The key or *spanner* by which it is turned should always be attached, and the nick which indicates whether it is open or shut should be distinctly marked. The cock should be literally a *stop*-cock.

2005.

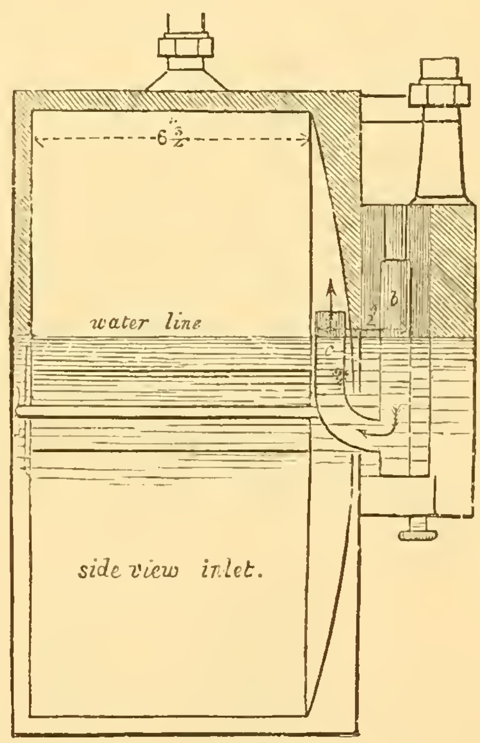


Throughout their various ramifications the pipes should have a slight inclination toward the point where the main cock is fixed, and thence to the street-main; this is to allow the water, which is occasionally deposited in them, to drain off without interrupting the passage of the gas. In fittings which are not thus arranged the water accumulates in some curvature of the pipes, and occasions an oscillation, or, as it is very commonly called, *jumping* of the lights.

2006.




2007




*Consumer's Meter.*—The consumer's meter is constructed upon precisely the same principle as that shown in Fig. 1982, but the partitions of the drum are differently arranged, and placed in such a manner that, as they reach the water, the surface presented shall be as small as possible, or the resistance offered shall be so gradual that the stream of gas flowing through the machine is uniform and constant. This is necessary in a meter from which any number of lamps are immediately supplied; because the most minute diminution or increase of the volume of gas flowing to them would cause a variation in the light, and produce an oscillation. In a station-meter the intervention of the gasometer will remedy this defect. A variation in the arrangement of the drum, therefore, is a matter of necessity.

As in the former case, the outer circumference or rim of the drum is divided into four partitions,

separated from each other by partition-plates, not running across directly at right angles with the face, but beveling from the plane of the water, meeting the wrap of the opposite hood. The sides of these partitions are also beveled; the space left between each plate forming on one side of the drum the inlet, and on the other side the outlet for the gas; the area of the latter being greater than the inlet, to insure perfect freedom of action. The dotted lines show the wrap of the hoods. Fig. 2005 is a view of the front or inlet side of the drum, with the convex cover removed. The outlets will present the same appearance, but of course reversed. By referring to Figs. 2006 and 2007, the remaining parts will be understood. The direction of the gas is marked by arrows. The box *a*, in which the inlet-valve is contained, is soldered tight, having no communication with the rest of the case, except through the valve, the position of which is shown by the arrows; *b* is the inlet-pipe projecting above the water-line, conveying the gas into the meter by the bent arm *c*, rising above the water between the convex cover and the inlet-hoods; *d* is a float attached to the inlet-valve, adjusted so that when the water falls below the centre opening the valve will close, and the gas cease to enter the meter.

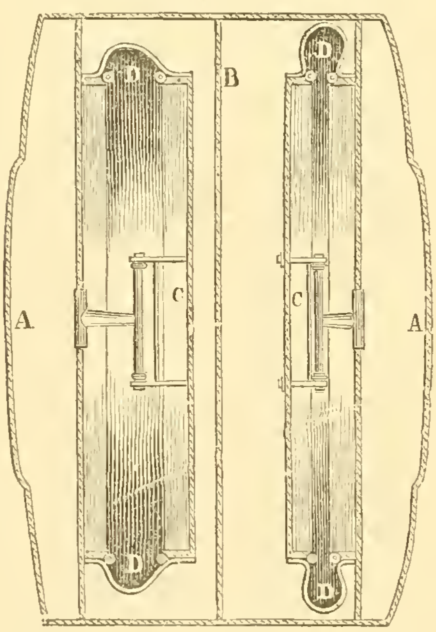
Motion is communicated to the train of wheel-work behind the index from a spiral worm *w*, fixed on to the axis of the drum, working into a wheel, the spindle of which passes through the tube *t*, sealed by dipping under the water contained in the case.

The following are the principal dimensions of consumers' meters:

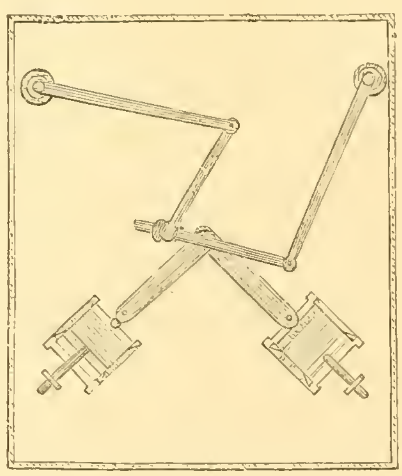
| Number of Lights. | Diameter of Drums. | Depth of Drums. | Diameter of Water Circle. | Centre Opening. | Hollow Cover projects— | Depth of Inner Hoods. | Depth of Outlet. | Capacity in Cubic Feet. |
|---|---|---|---|---|---|---|---|---|
| | Inches. | Inches. | Inches. | Inches. | Inches. | Inches. | Inches. | |
| 5 | 12¼ | 5 | 3½ | 1¾ | ¾ | ½ | ¾ | .25 |
| 10 | 14¾ | 6¾ | 3¾ | 2 | 1 | ⅝ | 1 | .50 |
| 20 | 17½ | 9⅛ | 4½ | 2¾ | 1⅛ | ⅝ | 1⅛ | 1.00 |
| 30 | 19½ | 10⅞ | 5 | 3 | 1¼ | ⅝ | 1⅛ | 1.50 |
| 50 | 21½ | 11¾ | 5 | 3¼ | 1⅜ | ¾ | 1¼ | 2.00 |
| 80 | 25 | 12¾ | 6½ | 4 | 1½ | 1 | 1½ | 3.00 |
| 100 | 27¾ | 13¾ | 7½ | 5 | 1¾ | 1 | 1½ | 4.00 |
| 150 | 33 | 20¼ | 9 | 6 | 2¼ | 1½ | 2 | 8.00 |
| 200 | 33 | 24¾ | 10 | 7 | 2¼ | 2 | 2½ | 10.00 |
| 400 | 44 | 30¾ | 15 | 10 | 2¾ | 3 | 4 | 20.00 |
| 800 | 60 | 40¼ | 21 | 15 | 4¾ | 5 | 5½ | 50.00 |

*Dry Gas-Meters.*—The ordinary wet gas-meter described is unexceptionable where fraudulent means are not employed for underestimating the amount of gas consumed, but its construction admits of great deception being practised by dishonest consumers. If, for instance, the water-level in the meter be lowered, more gas will pass through than is registered by the instrument; if the case of the meter be tilted forward to an angle of from 5° to 13°, according to its construction, and a proportion of the water drawn off, so as to expose the outlet of the measuring chamber, the gas will pass through it without affecting the index, and without being registered at all. This is constantly done, and the large amount of gas which is unaccounted for in the calculations kept at the gas-works, and which is frequently attributed to leakage, is no doubt traceable to this nefarious practice. In cold weather the water in the meter is liable to freeze, and the passage of the gas is then completely stopped. The use of a solution of caustic potash or soda has been proposed, which is not so easily

2008.




2009.



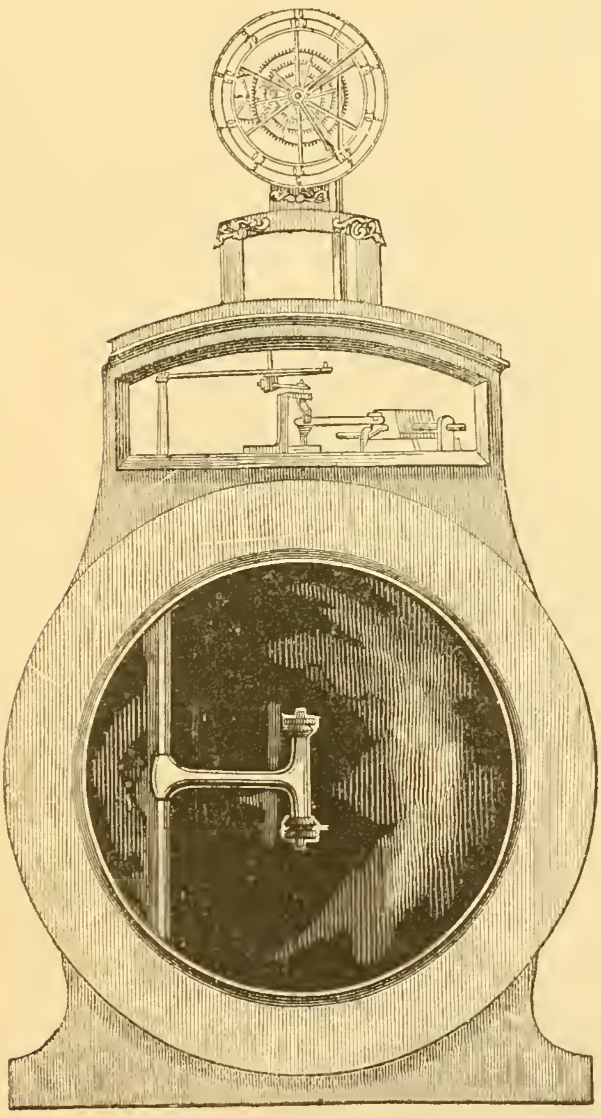
affected by frost, to replace the water in the meter, which will also tend to render the gas more pure, should either carbonic acid or sulphuretted hydrogen have escaped the general purifiers. The objections to the use of the wet meter stated above have given rise to great ingenuity in the construction of a variety of measuring instruments, in which the use of water or any liquid is dispensed with, and in which the gas is measured by the number of times that a certain bulk will fill a chamber capable

of undergoing contraction and expansion by the passage of the gas. These alternate contractions and expansions of the chamber set certain valves and simply constructed arms in motion, which, by the aid of a few wheels, can be made to turn the hand of a dial, as in the ordinary wet meter.

Messrs. Croll & Richards's meter consists of a cylinder or case *A A*, Fig. 2008, divided by a plate *B* in the centre into two separate compartments, which are closed at the opposite ends by metal disks *C C*. These metal disks serve the purpose of pistons, and are kept in their places by a kind of universal joint attached to each. The space through which the disks move by the action of the gas, which affords the means of measurement in this meter, is governed by metal arms and rods, shown in Fig. 2009, which space, when once adjusted, cannot vary. To avoid the friction attending a piston working in a cylinder, a band of leather *D D* is attached, which acts as a hinge, and folds with the motion of the disk; this band is not instrumental in measuring the gas, so that its contraction or expansion would only decrease or increase the capacity of the hinge, the disk being still at liberty to move through the required space only. The leather is also attached in such a manner that it can only bend in one direction, and this renders it much more durable.

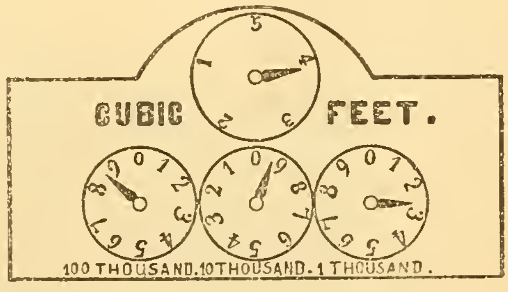
The gas enters the cylinder at the top, from the space occupied by the arms, valves, etc., Fig. 2010, and forces the disks bodily forward through a certain space; the motion communicated by the disks to the arms and rods causes the supply of gas to be cut off, and admits of its escape by another valve; at the same moment the gas is admitted to the other side of the disk, and this is forced to return to its original position, traversing, of course, the same space as before. Each backward and forward motion consequently indicates the passage of a constant quantity of gas, and the same apparatus which admits and shuts off the supply by means of valves is connected with clock-work; and thus the motion of the disk, or the quantity of gas which has passed through the meter, can be indicated upon a dial-plate, as in the ordinary wet meter.

2010.



*Comparative Advantage of Wet and Dry Meters.*—Wet meters are simpler in construction than dry meters, having no valves except the float, but they are liable to freeze and stop on account of too much or too little water. Dry meters are therefore more generally used, although they are more liable to get out of order, as the wear and tear is greater; but the inaccuracies from wear or corrosion are generally in favor of the consumer. The water in wet meters is sometimes replaced by glycerine or water in which chloride of calcium is dissolved, to prevent evaporation, thereby keeping the liquid all the time at the same level.

2011.



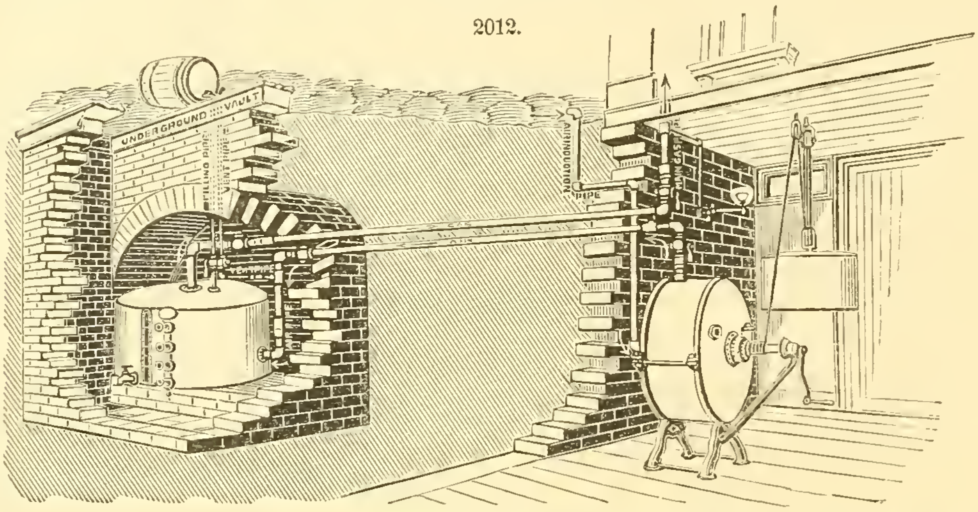

The index of the meter, Fig. 2011, is very simple. Each figure or division on the faces indicates as follows: On the right-hand face, 100, 200, 300 cubic feet, etc.; on the middle face, 1,000, 2,000, 3,000, etc.; on the left-hand face, 10,000, 20,000, 30,000, etc.; and, in this way, multiplying by 10 for every additional face. The face in the centre or top indicates the fractions, as 1 foot, 2 feet, and so on, and it is used in testing the governor. When there are 10 or more burners lit, the hand may be seen to move; the more burners lit, the faster it will move. Look at the left-hand face of the index and set down the figure the pointer has passed, which on the above diagram is 8; next look at the middle face, and set down the next, which in the diagram is 9; next upon the right-hand face, and take the same relative figure, which is 2; and you have the number 892, to which add two ciphers to represent hundreds, and the sum of 89,200 is shown as the present state of the meter. H. A. M., Jr.

GAS, ILLUMINATING, MACHINES FOR PRODUCING. When buildings are situated beyond the reach of the gas-mains of cities, it becomes necessary to find a substitute for coal-gas. One of the best is the gas produced by bringing a current of air in contact with gasoline. This fluid, being of a volatile character, readily throws off carbonaceous vapors, which, combining with the air, pro-

duce a gas that burns, when properly regulated, without smoke or odor, and furnishes an agreeable light.

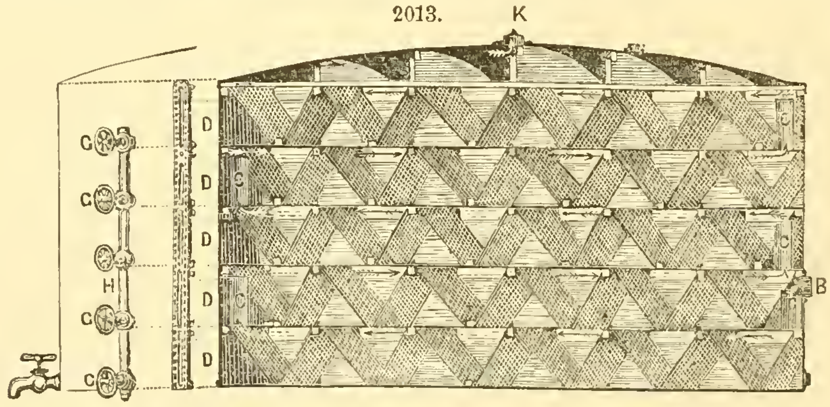
*The Springfield Gas Machine* is shown in Fig. 2012. An air-pump operated by a weight is used

2012.



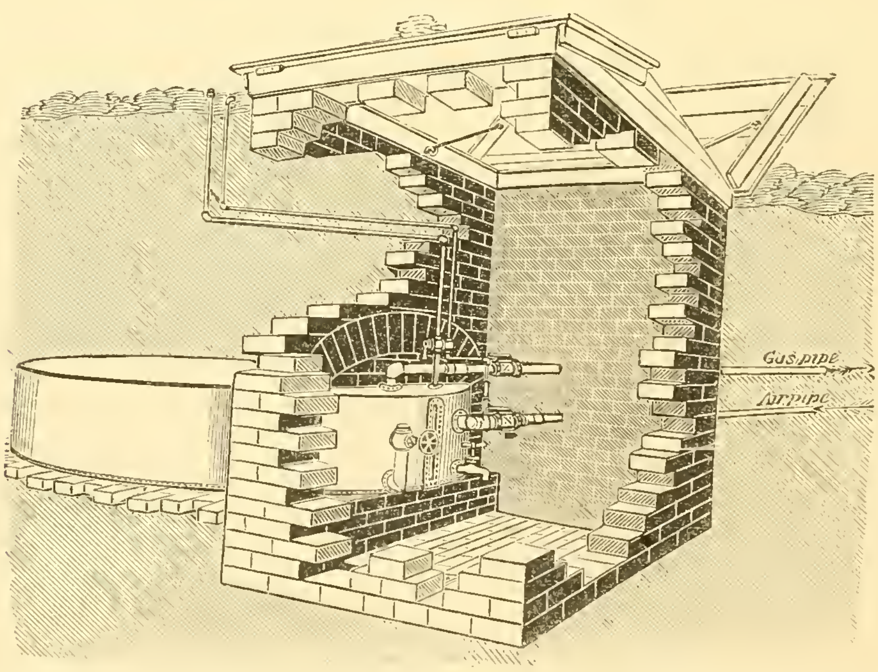

to produce the air-current. The gas-generator is a cylinder containing evaporating pans or chambers, in which the gasoline is kept. The generator is always placed in a vault under ground, removed from the building a safe distance; or it may be buried in the earth. The air-pump is sta-

2013.




tioned in the cellar of the building to be lighted. Supposing a machine to be set up and connected by pipes, as shown in Fig. 2012, the generator to be filled with gasoline, and the weight of the pump wound up, the process of gas-making is as follows: The action of the pump draws a supply

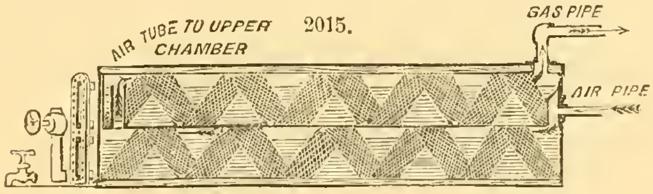
2014.



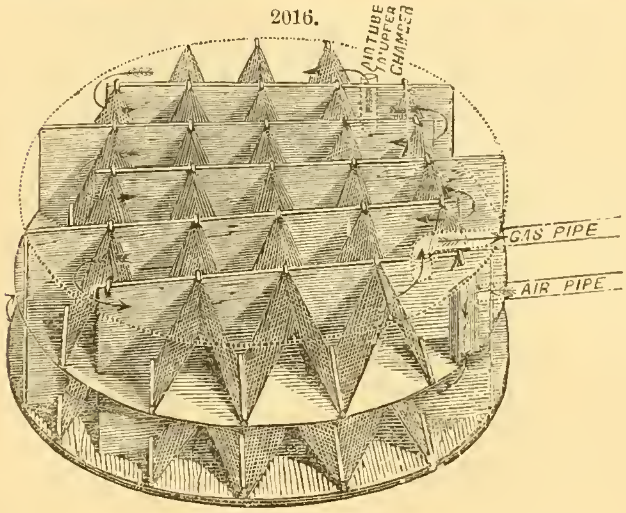

of air through the induction-pipe leading to the gas-generator; in its passage through the generator it becomes carburetted, thus forming an illuminating gas that is returned by the gas-pipe to the

burners within the building. The machine is automatic in its operations, gas being made only as fast as consumed. When the burners are shut off, the pump stops and the manufacture of gas ceases, but immediately commences when they are opened again. The gas-generator is recharged whenever exhausted, usually once in from three to six months, varying according to the rapidity of the consumption of the gas. Gauges on the generator show at any time the amount of fluid it contains, and when it needs to be replenished. A double-way cock connecting with both the filling and vent pipes in the vault is used, so that of necessity a free vent is given while filling, thus preventing any

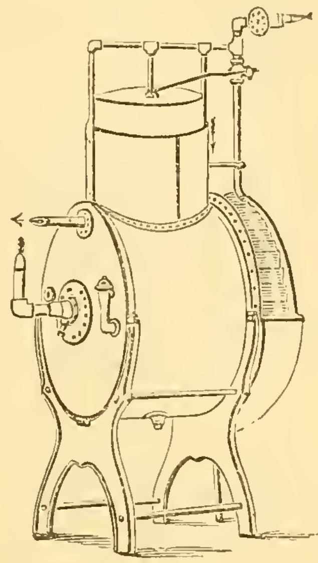
2015.




2016.



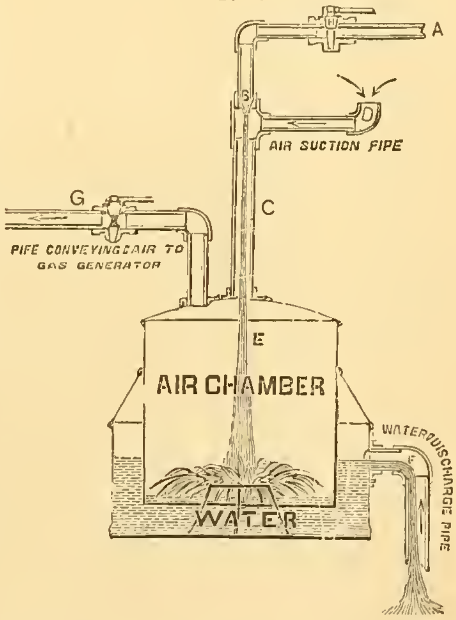

2017.



backward pressure of the gas upon the pump or strain on the generator. The weight of the pump does not commonly require winding oftener than once or twice a week, and this takes but a moment's time. There is a retaining power spring within the pump that drives it while the weight is being wound, operating on the same principle as that of a watch, which enables it to be wound without stopping its movement.

Fig. 2013 is a sectional view of the gas-generator, showing its series of evaporating chambers. The gasoline, as it enters the generator, fills the uppermost chamber first, to the top of the overflow tube *C;* this tube allows of its passage to the next chamber below; this in turn filling afterward the one below this, and so on successively until all are filled, and the fluid appears in the lowest chamber at say two-thirds the height of the lowest gauge *G*. The filling-cock then being shut, the apparatus is ready for use. Air forced by the pump or hydraulic blower enters the generator at *B*, passes over the fluid and through the meshes of fibrous capillary material, now thoroughly saturated with gasoline, back and forth through the subdivisions of this chamber, then up through the tube *C* to the next chamber above, winding through this in a similar manner, afterward through the chamber still above this, and so on; until finally, becoming thoroughly impregnated with the vapor arising from the gasoline, it is delivered a rich carburetted air-gas, through the gas-tube *K* to the burners of the building to be lighted.

2018.




In Fig. 2014 is shown a "flat" gas-generator. The modification consists in making the evaporating chambers of greater diameter and fewer but larger, and so arranging the connections for the air, gas, and filling pipes that they may be substantially buried in the earth, only an arc of a circle projecting into a little brick pit.

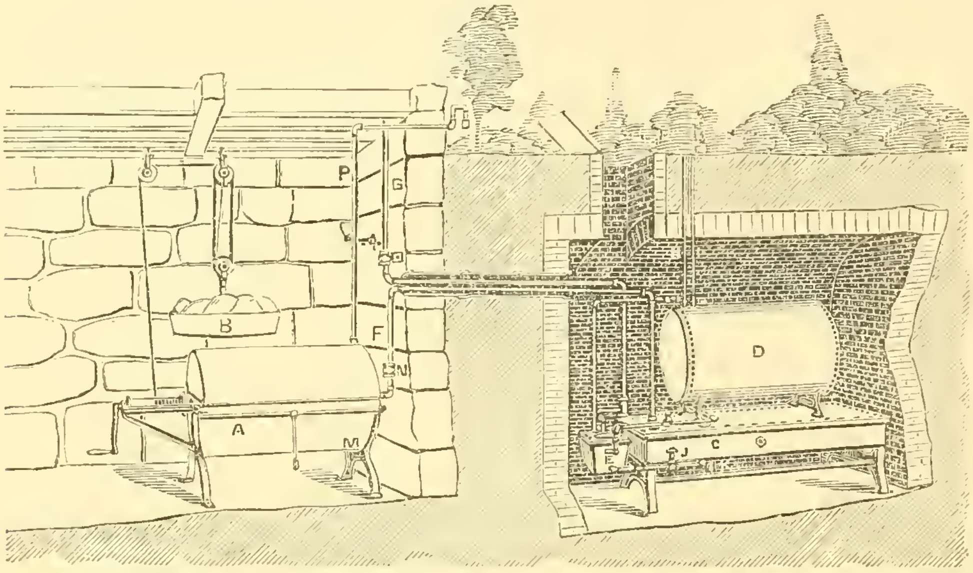
Fig. 2015 is a perspective sectional view of the "flat" generator, showing the wooden division-frames and the capillary webbing stretched upon them; also, by the arrows, the direction taken by the air in passing through. Fig. 2016 is also a sectional view, as it appears when charged with gasoline.

Fig. 2017 shows an ingenious improvement in the apparatus, whereby the air-pump is operated by water and a water-wheel. Where a fall of water is available, it is made use of to operate a "hydraulic blower," which is substituted for the air-pump driven by weight. The hydraulic blower is shown in section in Fig. 2018, and consists of two copper vessels, one inverted in the other,

to which are attached pipes as shown. The injection-pipe *A* brings water from the flume or other source of supply. This pipe is fitted with the nozzle *B*, through which the water rushes, falling through the larger pipe *C*; in so doing, air is drawn in at the suction-pipe *D*, and both water and air fall together into the inverted vessel *E*, where the air is confined. The water passes off through the discharge-pipe *F*. Through the pipe *G* air is conveyed to the gas-generator. Where a head of water of 4 feet or more can be obtained, it can be used with perfect satisfaction. The cost of gas made by this process is from $1 to $1.50 per thousand feet, 6 gallons of gasoline making, it is claimed, a light fully equal to 1,000 feet of coal-gas.

*The Solar Gas-Generator* is represented by Fig. 2019. *A* is an air-pump propelled by the weight *B*. *F* is the air-pipe, through which air is forced into the carburetter *C*, where it unites with the vapor of gasoline, thus producing the gas, which is carried through the pipe *G* to the burn-

2019.




ers. *D* is an iron reservoir for containing a large supply of gasoline. *E* is the automatic filler, which regulates the supply of gasoline to the carburetter. *H* is the filling-pipe, through which the gasoline is poured into the reservoir. *I* is a vent-pipe to allow the escape of gas while filling. *J J'* are globe valves for the purpose of confining the gasoline to the reservoir and carburetter, whenever alterations may be required. *K* is a draw-off cock, which can be opened with an ordinary wrench. *L* is a vacuum-pipe for the purpose of preventing a vacuum, which would otherwise occur in the reservoir and automatic filler. *M* is a plug for drawing off the water from the air-pump. *N* and *O* are gas-cocks for shutting off the pressure from the air-pump and generator. *P* is the induction-pipe, which supplies air to the air-pump. The reservoir is intended to contain a supply of gasoline for six months, more or less, according to dimensions selected by the purchaser. The gasoline is transported in barrels, and poured directly into the reservoir by means of a rubber hose, one end of which is attached to the barrel by a faucet, and the other to the filling-tube, as shown at the surface of the ground. The automatic filler performs the important function of supplying gasoline to the carburetter in exact proportion to the consumption of gas; by which means a most desirable result is secured, not otherwise attainable, viz., uniformity of light. H. A. M., Jr.

GAS, ILLUMINATING, PROCESSES OF MANUFACTURE OF. The principal processes of manufacture of illuminating gas are given in some detail in the following article, beginning with the various systems in use by the large gas companies which supply the city of New York.

*Manhattan Gas-Light Company's Process.*—The gas is manufactured directly from coal, three kinds of which are used, viz., Westmoreland, Nova Scotia, and cannel. These varieties are mixed together, the mixture containing about 10 per cent. of cannel coal, which is the enriching material, furnishing those hydrocarbons desirable for illumination. The mingled coals are introduced into the retorts, which are 1,000 in number, mostly arranged in benches of five or six. The charges weigh from 200 to 250 lbs. The retorts previous to the introduction of the coal are heated to from 2100° to 2300° F., which raises the temperature of the coal to from 1500° to 1600° F. The distillation takes from 4 to 4½ hours, when the retorts are opened, the residue of the coal (coke) is withdrawn, and new charges of coal are inserted. During the process of distillation, the gas passes up the stand-pipe, then down the dip-pipe into the hydraulic main. Thence it goes to the large condensers, which are two in number, and afterward enters the dry scrubbers. Here it passes over a large number of surfaces, and deposits thereon any tar which it may contain. The gas next proceeds to the scrubber proper, where it meets with an immense number of moist surfaces which remove the ammonia. Only from 1 to 1½ gallon of water is used for 1,000 feet of gas.

The scrubbers are two in number, 85 feet high, the gas-way being 60 feet. Being exposed to the air and consequently to fluctuations of temperature in winter and summer, the scrubbers are surrounded with an iron jacket, near the bottom of which are steam-pipes for heating the air in the jacket, which is kept in circulation by suitable openings at top and bottom. Steam is used only in winter, to keep the water in the scrubbers from freezing, as generally the colder the water is the better is its absorbent power.

From the scrubbers the gas is forced through the purifiers, which are 12 in number, containing

from 500 to 600 bushels of lime each. The tops or covers are removed by machinery and transported on a tramway. The gas is passed through sets of 4 purifiers, whence it is forced into the meters, which are 15 feet in diameter and 12 feet deep. Finally it passes to the holder ready for consumption.

About 1,000,000,000 cubic feet of gas is made in a year by this company, the amount daily produced being from 1,000,000 to 5,000,000 cubic feet. The candle-power averages (with the city burner) 17½ candles. About 1,700 lbs. of coke is produced from 2,240 lbs. of coal. The exhauster is situated in these works between the condenser and scrubbers. The water used at the works is from a driven well. About 175 tons of coal is used per day. The lime from the purifiers is sold as a fertilizer at half a cent per bushel.

*The New York Gas-Light Company's Process.*—Penn, Rock, and cannel coals are used at the works of this company. The mixture of these three varieties is introduced into the retorts in charges of about 240 to 280 lbs. The retorts are charged 5 times in 24 hours, and are arranged in benches of 6, there being 12 clay retorts with lead lids. The gas after leaving the retorts passes up the stand-pipe, then down the dip-pipe into the hydraulic main, whence it is forced through two large multitubular condensers. It then enters a large revolving scrubber 40 feet high, every other tray of which revolves. The gas is next forced through one lime-purifier containing 600 bushels of lime, passes through a 30-inch leader to the iron-purifiers, but branches off in two 20-inch pipes on one side of the purifier, uniting on the other side again in a 30-inch leader. The gas passes through a set of three iron-purifiers, then to the meter, and finally to the holder ready for consumption. The exhauster is situated in front of the condenser. The average amount of gas made per day is over 3,000,000 cubic feet. There are a number of holders at the works, two of which have a capacity of 1,500,000 cubic feet each. The greatest pressure of gas at the works is 5.8 to 6 inches, being 1.6 inch at the office. The works are situated at 21st Street and East River, and the gas is not distributed until it reaches Grand Street (about 2 miles distant); hence the cause of high pressure. The candle-power of the gas, with the city burner, is 16.5 candles.

*The Harlem Company's Process.*—Virginia coal, at $5.25 per ton, is used alone at the works of this company. There are 52 benches containing sets of 5 retorts. The charge per retort is on an average 200 lbs., requiring 4 hours for the distillation, 6 charges being introduced in 24 hours. The gas is drawn from the retorts and ascends the stand-pipe, then descends the dip-pipe into the hydraulic main, whence it passes into a St. John & Rockwell scrubber. It is then forced through a large scrubber about 40 feet high. It next traverses three purifiers containing oxide of iron, and thence passes to the meter, and to the holder ready for consumption. About 2 gallons of water is used in the scrubber to about 1,000 cubic feet of gas, the wash-water from which contains 6½ ounces of ammonia to the gallon. About 1,550 lbs. of coke is produced from a ton (2,240 lbs.) of coal. The pressure of the gas at the works is 3 inches. It is claimed that 11,000 cubic feet of gas is obtained from a ton of coal. The candle-power of the gas, with the company's burner, is 17½ candles.

*The Metropolitan Gas Company's Process.*—In the works of this company naphtha is substituted for cannel coal to produce the necessary hydrocarbon. Virginia coal is used in summer and Penn or New Castle in winter. There are 560 clay retorts, arranged in benches of 6 each. The charge is about 240 to 250 lbs. The gas from the retorts passes up the stand-pipe, then down the dip-pipe into the hydraulic main. It is then drawn into a large multitubular condenser, after passing through which it is forced through two large scrubbers, one containing ammonia liquor and the other water. It then goes through a set of three purifiers, which are filled with a layer of sawdust moistened with acid, then a layer of oxide of iron, and then four layers of lime. From the purifiers the gas passes to the meter and then to the holder. This gas, which has a candle-power of from 12 to 15 candles, is afterward enriched with naphtha gas, which is prepared in 12 "through retorts," which contain iron tubes extending half the depth of the retort. The naphtha is made to pass back and forth through the tubes until it is thoroughly vaporized, when it escapes out of the pipe through to the other end of the retort, and is rendered by the intense heat a more or less permanent gas. It is sometimes mixed with the coal-gas just before the latter enters the condenser, and then passes with the coal-gas through the condenser, scrubber, etc., to the holder; or the naphtha gas is itself passed through a separate condenser, scrubber, and meter, and mixed while more or less hot in the pipes in its passage to the holder. It is claimed at these works that 73 cubic feet of naphtha gas (of 60-candle power) is obtained from 1 gallon of naphtha, and that from 1 ton (2,240 lbs.) of coal from 11,000 to 12,000 cubic feet of gas is produced. The largest amount of gas manufactured per day is 3,200,000 cubic feet in winter and 800,000 cubic feet in summer. The candle-power, with the company's burner, is from 18 to 19 candles. The McKenzie exhauster is used after the condenser and scrubber.

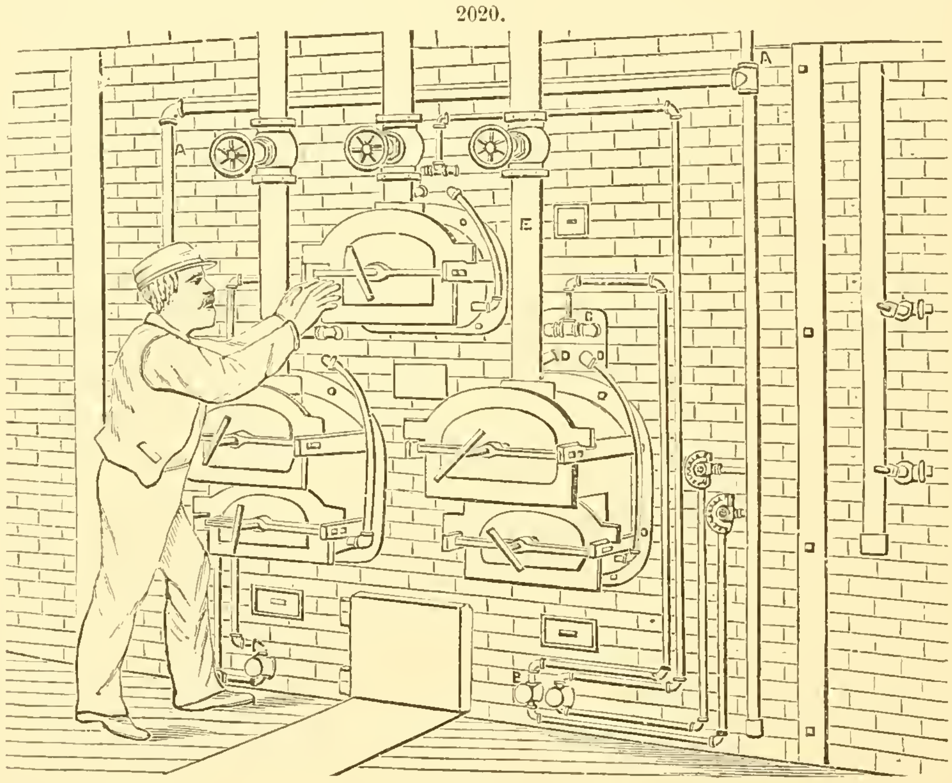
*The New York Mutual Gas-Light Company's Process.*—This company claims to obtain from 1 ton of coal from 16,000 to 18,000 cubic feet of a gas of only 1 to 4 candles luminosity. This, after proper purification, is enriched by naphtha up to any candle-power, generally about that of 20 candles. The process is as follows: After leaving the retorts the gas passes through the stand-pipe, the dip-pipe, and the hydraulic main, and then through a 16-inch pipe to 8 large coolers (condensers), which it successively traverses, and finally enters two large scrubbers, whence it proceeds to the purifiers. The coolers and scrubbers contain scrap-tin, which gives innumerable surfaces for the gas to meet. The first purifier contains oxide of iron, which robs the gas of its sulphur compounds. The gas then passes through purifiers containing lime, which takes up the carbonic acid, and then goes to the temporary holders in the form of purified light carburetted hydrogen, heavy carburetted hydrogen, and hydrogen. From the holder the gas passes to the carburetter, where it is enriched with the vapor of naphtha. It then passes through a long distributing reservoir (hydraulic main) to the through retorts. On leaving these it traverses the stand-pipe, dip-pipe, and hydrau-

lic main, and lastly is forced through five coolers (condensers) containing as before scrap-tin. The candle-power, with the company's burner, is 20 candles.

*The Municipal Gas-Light Company's Process.*—This company uses a new process invented by Tessié du Motay. Water instead of coal is used as the element for producing the foundation of the gas, which is afterward enriched by naphtha vapor. The light is remarkable for its whiteness. The process is as follows: In a large boiler water is converted into steam, and passes into a large iron cylinder, known as the "gasogene generator," which is filled to three-fourths of its height with coal. The coal is first heated white-hot by means of a blast, and when in this condition the blast is turned off and the steam is admitted. Decomposition of the steam at once takes place; hydrogen gas and carbonous oxide gas are formed, which take up of course the impure gas given off from the coal. The gas then passes up a stand-pipe and down a dip-pipe into a large rectangular iron vessel containing water, through which it proceeds to a temporary holder of 125,000 cubic feet capacity. From the holder the gas goes to the carburetters, where it is enriched with naphtha vapor volatilized in the carburetter by means of a steam-jacket. It then passes to the through retorts, which are highly heated, and on passing through the naphtha is decomposed into higher hydrocarbons, which tend to make a more stable gas. From the retorts the gas passes up a stand-pipe and down a dip-pipe into the hydraulic main, whence it passes to the condensers, then through the scrubbers to the purifiers, then through the meter, and finally to the holder ready for consumption. The exhauster is situated after the condenser and scrubber. The pressure of gas at the works is 2.7 inches; at $1\frac{1}{2}$ mile distant, 14 inches. From 1,000,000 to 3,000,000 cubic feet of gas is made per day, having with the company's burner an illuminating power of 22 candles. Six gas-holders are used, capable of holding 18,000,000 cubic feet of gas.

*The American Hydrocarbon Process.*—The method formerly known as the Gwynne-Harris process,

2020.



but now as the Allen-Harris or American hydrocarbon process, was successfully introduced into the city of Poughkeepsie in 1875. Three double retorts of fire-clay are employed; each retort has a horizontal diaphragm extending from front to rear, dividing it into an upper and lower retort, with small holes through the rear half of the diaphragm. The three are set in a bench like retorts for coal-gas, as shown in Fig. 2020. In the bottom of the lower retort chambered tiles are laid, closely joined and cemented, forming a false bottom. The rear half of the upper surface is perforated with small holes. Two fire-clay superheaters, $6\frac{1}{2}$ by $9\frac{1}{2}$ inches in size, and 5 feet in length, having a hole $1\frac{1}{2}$ to 2 inches in diameter, extending from the front to near the rear, and returning again to the front, are laid upon or at the side of each retort in the bench. Near the foot of the bench wall, in a small chamber about 4 inches square, is placed a drier, consisting of a metal pipe about 5 feet long, with a smaller one within it, to prevent the possibility of any water or condensed steam from reaching the red-hot clay superheaters or retorts. The steam is generated by a boiler of suitable size; and where a rapid production of gas is required, an independent superheater is built alongside of the boiler, consisting of an oven in which are iron pipes, 5 to 6 inches in diameter, filled with coiled steel wires or shavings, and passing back and forth in the oven. The steam, by a connecting-pipe, is sent from the boiler into this superheater, where it is raised to about 700° or 800°, or even to 900°; from here it passes through the drier, and thence into and through the fire-clay superheaters, which lie in the hottest part of the bench, and by which it is raised to about 2500°. In this state the steam enters the chambered tiles, and is carried back, and passes up through the small perforations, by which it is distributed in finely-divided jets, under and through the incandescent anthracite coal in the lower retort, and in like manner through the perforations in the diaphragm and the

incandescent anthracite coal in the upper retort. The steam is thus perfectly decomposed, with great rapidity and at a small cost. As each particle of steam comes in contact with the incandescent coal, the oxygen in it unites with an atom of carbon, forming carbonic oxide, and its hydrogen is set free; the result being hydrogen and carbonic oxide, which are the most incondensable of all gases. To give illuminating power to this gas, where the daily production is large, a separate bench is set with like retorts, but without any of the above-mentioned fixtures, and without containing any coal, coke, or other materials. This bench is also kept at a high heat, and into these retorts the water-gas is sent from two adjoining hydrogen benches; and at the same time an exceedingly small stream of naphtha is constantly flowing in, and, being converted into gas, this unites with the water-gas, and gives it its illuminating power. The gas, thus perfected, passes up the stand-pipe into the hydraulic main, and thence through the condensers, purifying boxes, and station-meters, to the holder, ready for use.

One bench in which the oil- and water-gases are thus united is sufficient to carburet all the water-gas from two hydrogen benches; and the three benches will readily make 100,000 cubic feet of gas per day. The labor of making this gas is very light. The hydrogen retorts are drawn and recharged once a week with anthracite coal, and every morning the fire is raked back, a few pounds of coal are thrown in front, and the lid is closed for 24 hours. The steam and oil are admitted into the retorts by cocks, and require no attention so long as the daily make of gas does not greatly vary; and even then it is only a trifling matter to regulate the same, increasing or lessening the quantity of either, as occasion requires.

In decomposing the steam 17 lbs. of anthracite coal, and in adding the illuminants from 3½ to 4 gallons of naphtha, to each 1,000 feet of gas, are used. Over 1,500,000 feet of gas has been purified with 24 bushels of shell-lime, averaging over 65,000 feet per bushel. When the use of rich gas coals is for any reasons perferred to that of oil, the same are carbonized in the retorts in the oil-bench, and the water-gas is introduced in the same manner as when oil is used, and the results are similar. The following is a statement from the Citizens' Gas Company of Poughkeepsie for the month of September, 1877:

Total gas manufactured, 1,592,400 feet. Average daily consumption, 52,970 feet. Average candle-power, 16.73. Materials, etc.:

| | |
|---|---|
| 18.70 tons stove coal, at $3.90 | $70 20 |
| 11.1144 tons grate coal, at $3.54 | 40 71 |
| 13.1880 tons chestnut coal, at $3.74 | 51 62 |
| 647 bushels of coke, at $0.09 | 52 23 |
| 96 bushels of tar, at $0.93 | 89 28 |
| 6,480 gallons of naphtha (average 4.06), at $0.07¾ | 502 20 |
| 4 men in works | 165 00 |
| Total cost | $971 24 |

Cost per 1,000 feet, 61⅓ cents delivered in holder.

One change of purifier, from July 28 to September 5. Gas made, 1,580,200 feet. Lime used, 24 bushels. Average gas purified per bushel of lime, 65,800 feet (shell-lime used).

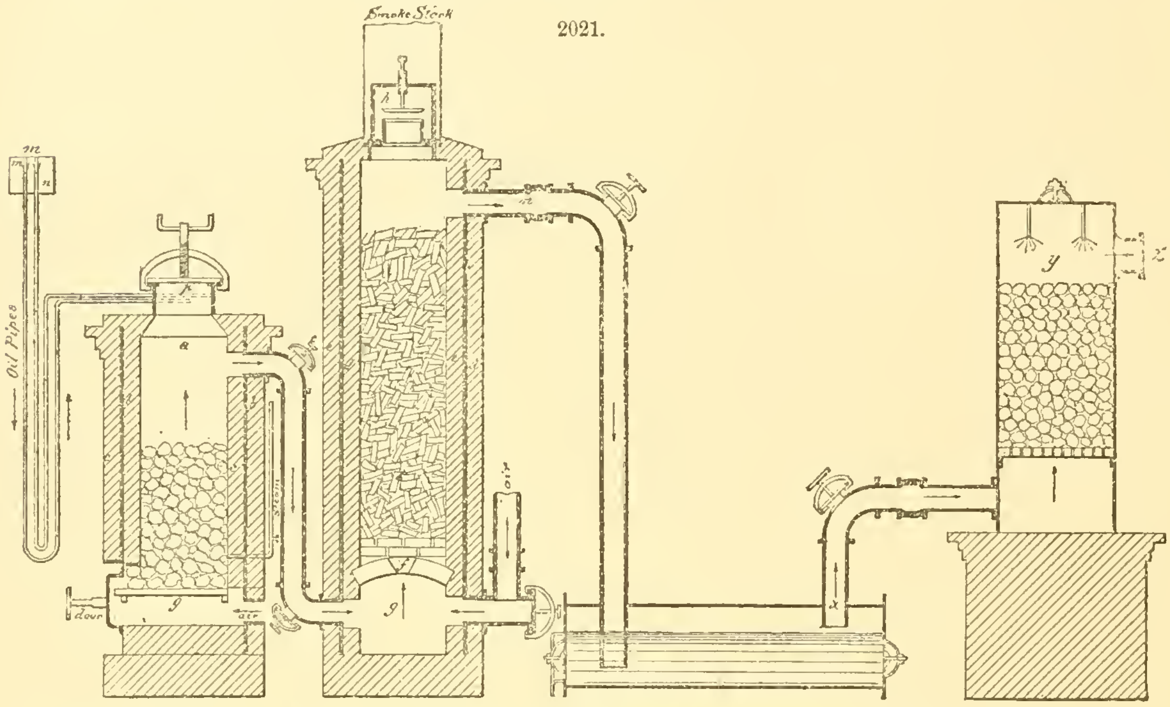
The cost of 1,000 feet of gas, as shown by this statement, is only 61⅓ cents; but this is higher than it would be if the works were running their full capacity. With an average daily consumption of 80,000 feet, the cost would not be over 50 cents per 1,000 feet, delivered in the holder.

*The Lowe Gas Process*, Fig. 2021.—This process had a nine months' trial in the city of Utica under the direction of Prof. Henry Wurtz, and gave excellent results, when, unfortunately, the works were destroyed by fire. "Fig. 2021 represents a section of one of the sets of apparatus, of which four are erected at Utica, although only two are, at the present season, kept at work; these being more than sufficient to supply the consumption of the town, which, during the month of October, 1875, was close upon 120,000 feet per day. On the left of the engraving is represented the gas-generator, 9 feet high and 28 inches in internal diameter, half filled with clean anthracite, broken to rather large 'egg size.' *p* indicates the man-hole for feeding the coal, almost flush with the second floor of the building, on which the attendant stands. The apparatus next on the right is called by the inventor the 'superheater'—a name used provisionally, though its functions are but imperfectly expressed thereby, being rather those of a regenerator. The dimensions of the superheater are 15 feet in height by 28 inches internal diameter. The first step in the process consists in blowing up the anthracite in the generator to intense ignition, by means of a blast of air entering under the grate *g*, at the point marked by the arrow. The highly-heated gaseous products, consisting of carbonic oxide and nitrogen, pass down through the pipe *f*, and, meeting in *g* another blast of air from the right, kindle again and blaze up through the mass of loose fire-bricks in the superheater, heating the latter to an intense temperature. During the first stage of blowing up the generator, the valve *h* at the top of the superheater is open, and the blast passes on to the boiler to help make steam. The second stage is to shut off the air-blast, to close the valve *h*, and to introduce steam into the side of the generator, through the small pipe marked 'Steam' passing down its right-hand side. Water-gas is now formed, and there is simultaneously fed into the top of the generator, trickling slowly in through the small siphon-tubes *m*, a certain amount of crude petroleum, of ordinary density, which, vaporized by the heat as it enters, is swept on to and through the superheater, in which it undergoes gasification; and the whole mixture passes on through *n*, down to the washer *v*, and on to the other arrangements provided for condensation. The amount of gas obtained at each heat is 3,000 cubic feet or more, according to the degree of heat attained, and the average time of each such heat, including both stages of blowing up the fire and generating the gas, is one hour; so that 24 heats, or over 70,000 cubic feet of gas, can be obtained daily from each apparatus."

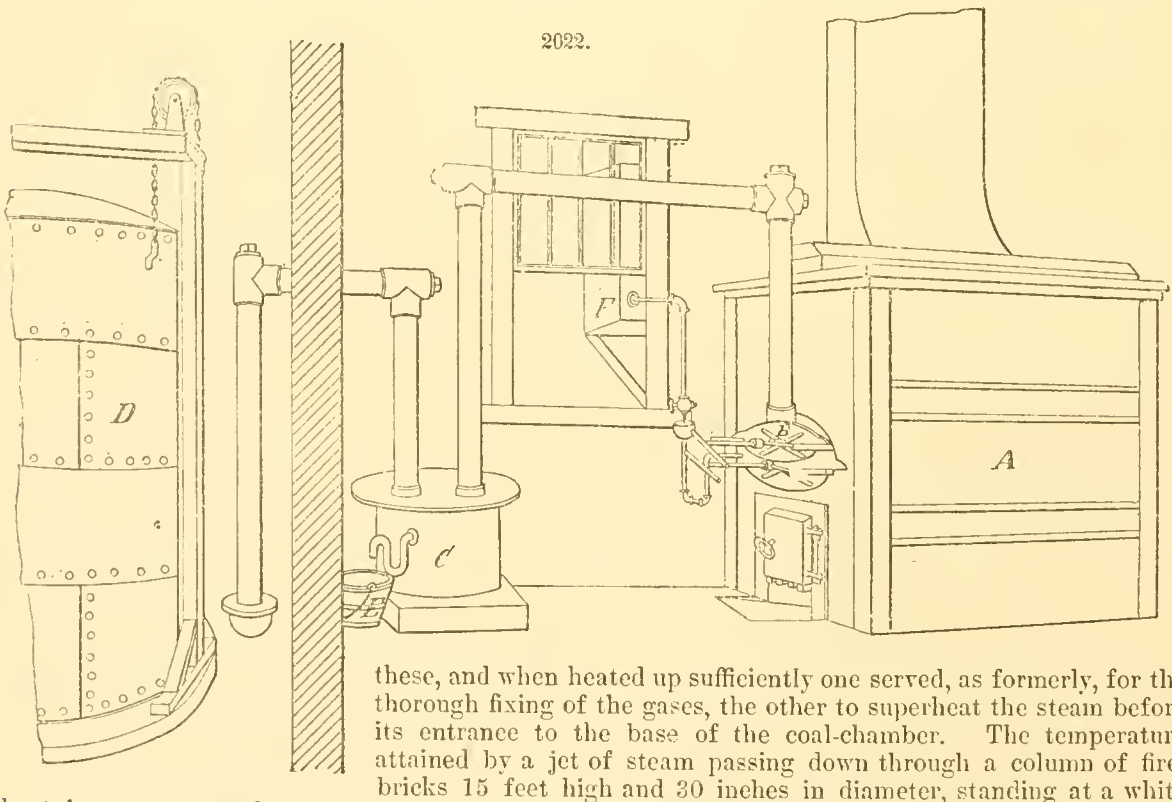
During the tests at Utica it was found that the cost of purification per thousand for labor and lime together was but 2.783 cents. Prof. Wurtz states that there appears no reason, so far as he can ascertain, why this low cost of purification should not be maintained. The candle-power of this gas, during the period of the analyses, was $19\frac{1}{2}$ candles for 5 cubic feet per hour. The density was found to be, mean of three determinations, .571.

After the burning of the Utica works, arrangements were made for another demonstration of this system with the Philadelphia Gas Trust, at their Manayunk station. The process, as recently "blown in" there, showed a decided advance in some particulars over the results obtained at Utica, owing to some alterations. The generators, of which there were three, were 40 inches in diameter, instead of 30 inches as before. To each of these there were two—instead of one as formerly—of the stacks called superheaters, filled with loose fire-brick. The products of combustion were divided between these, and when heated up sufficiently one served, as formerly, for the thorough fixing of the gases, the other to superheat the steam before its entrance to the base of the coal-chamber. The temperature attained by a jet of steam passing down through a column of fire-bricks 15 feet high and 30 inches in diameter, standing at a white heat, is enormous, and produced surprising results. The increased facility of generation was immediately noticed; the delivery of gas, instead of 3,000 feet, which was considered a good result at Utica, at once attained 8,000 feet to a run of 30 minutes in one generator. Two days later, over 10,000 feet was run, and subsequently 13,400.

2021.




2022.



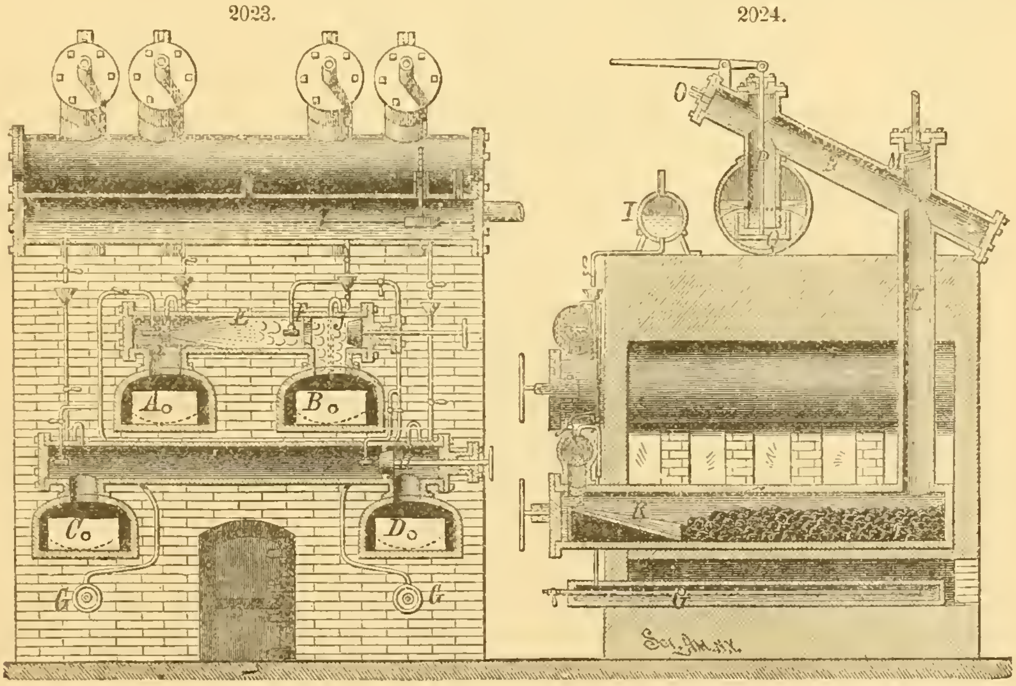

*The Wren Gas Process.*—The common objection to oil-gas is that it does not come to the consumer in the shape of a permanent gas. That is, the hydrocarbon is not fully gasified, but is rather in a

semi-vaporous state; consequently the gas leaves a deposit in the pipes, and smokes when burned. In the Wren system this difficulty is claimed to be obviated by the construction of the retort used, which is divided by longitudinal partitions into chambers. The oil, entering one of these, is vaporized, and the vapor then passes through the retort from end to end four times in traversing the compartments. As a large-sized retort enters 6 feet into the fire, it will be seen that the gas traverses 24 feet of heating surface, and in doing so it changes from a vapor to a permanent gas. Fig. 2022 exhibits the construction of the works. The crude petroleum from the receptacle *F* passes into an inverted siphon, which communicates with one of the chambers of the retort *B*, which is imbedded in the furnace *A*. It will be noticed that this construction prevents any danger of explosion of the retort, because, as soon as the stand-pipe chokes, the pressure in the retort meets the oil and stops the inflow, the oil running over the funnel of the siphon; consequently no more oil can get in and no more gas can be made until the excessive pressure is relieved. The stand-pipe conducts the gas to a washing-vat *C*, and thence it passes to a receiver *D*.

The inventor states that the portable form of this apparatus, the retort of which is 6 feet in the fire, 13 inches high, and 17 inches wide outside, will produce as much as 10 large 9-foot gas retorts, or 40,000 cubic feet of gas per day of 24 hours. To produce petroleum-gas, the equivalent in illuminating power of 25,000 feet of coal-gas, using the single retort, it is further stated that 300 lbs. of coal will be consumed in 24 hours' continuous run. The cost of making the gas is estimated as follows, prices being those obtaining in 1878: 50 gallons of petroleum, at 6 cents, $3; one-fourth ton of coal, at $8 per ton, $2; labor, $4; total, $9, or 36 cents per 1,000 feet of 80-candle gas. Gas made by this process is unaffected by temperature, and retains all its properties over an indefinite period. It has been stored in a cylinder for four years, and then found to have left no deposit and not to be impaired in its illuminating properties. It is well adapted for enriching coal-gas of 11-candle or other low power. One part of petroleum-gas to 5 parts of coal-gas makes a 17-candle light; to 4 parts, a 21½-candle light; and to 3 parts, a 30-candle light. It is also suitable for heating purposes, and especially so for iron- and steel-working, owing to its freedom from sulphur.

*The Adams Gas Process.*—Each bench contains four full-sized clay retorts. These are connected in pairs, each pair being a unit, so to speak, for the purposes of the process, the *rationale* of which is as follows: Retort No. 1 is charged with gas coal in the ordinary way and heated. Two hours afterward retort No. 2 of the pair is also charged, and the products of the fresh charge, tar, aqueous vapor, etc., which are given off before the temperature reaches the point when good illuminating gas is evolved, are led directly into the now highly-heated first retort. On the way they are mixed with superheated steam and petroleum vapor. The mingled gases combine with those in retort No. 1 for two hours. Then the charge in that retort is drawn, a fresh charge put in, and the first products of distillation are led into retort No. 2, reversing the former operation. In this way the alternation continues. The inventor, Prof. H. A. Adams, of New York, claims that the gas thus made reaches

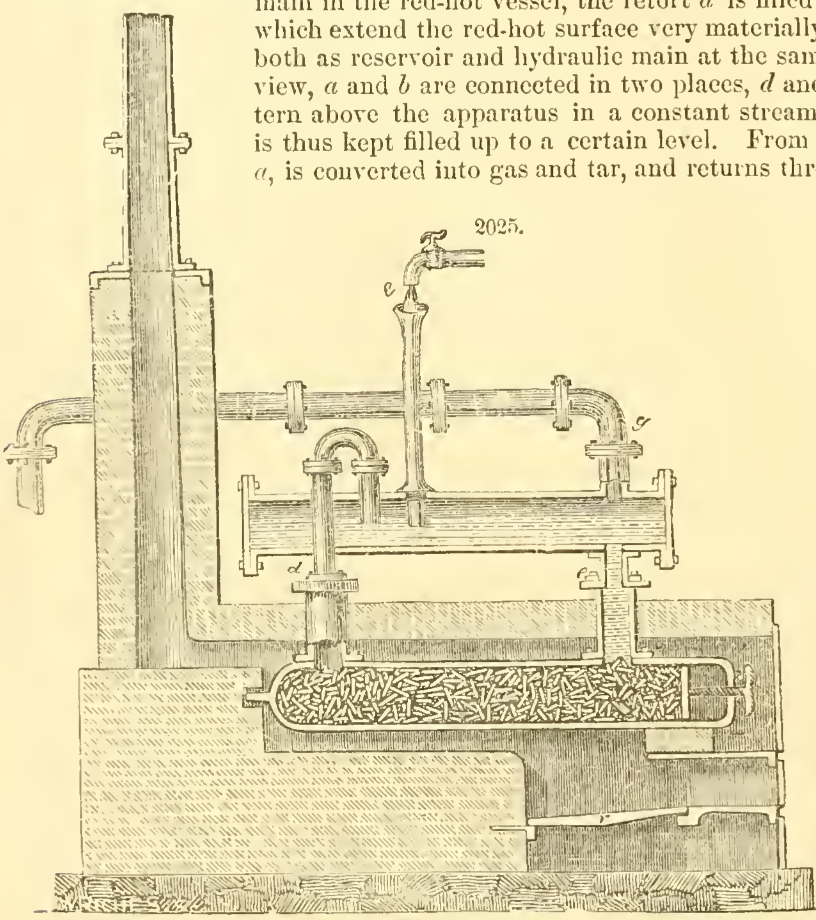
2023. 2024.




over three times the amount which coal alone is capable of producing in the same number of retorts of similar size; and he further asserts that the three gases, namely, from petroleum, from water, and from coal, unite in the retort to form a fixed gas of excellent quality and fine illuminating properties. From the sectional views, Figs. 2023 and 2024, the construction of his apparatus will readily be understood. Referring to Fig. 2023, *A* and *B* constitute the upper pair and *C* and *D* the lower pair of retorts. As the process is the same in each couple, we shall refer, for convenience, chiefly to the upper pair. These in front of the bench are connected by the horizontal pipe *E*, in which the mixing of gases is effected. At *F* are the steam nozzles, which, as shown in Fig. 2024, connect by suitable pipes with the superheater *G*. These are simply clay retorts or pipes placed in the lower flues of the furnace, and into which the saturated steam from a boiler is discharged. It will be seen from Fig. 2023 that the products of distillation from retort *A*, freshly charged, are passing over into

retort $B$, which has been in operation for two hours. The steam-jet is seen in operation on the left, and it will also be noticed that the valve $H$, which shuts off communication in the pipe $E$, between the retorts, is open. In the pipe between the lower retorts it is represented closed. The object of this valve $H$ is to shut off connection between the retorts when charging one so as not to lose the gas from the other. At $I$, Fig. 2024, is the reservoir for oil, which escapes in a fine stream, easily regulated, at the nozzle $J$, falling into the retort and upon an inclined apron or gutter $K$. This last is placed in the mouth of each retort, when the latter is charged with coal, for the purpose of causing the liquid to flow back into the hotter portion of the retort, aud so conducted to the hottest part of the coal therein. At $L$ are the four stand-pipes which are connected to the rear ends of the retorts. The object of this arrangement is to compel the gas-tar and aqueous vapors formed in the front ends of the charges to pass through the red-hot ends of the retorts and escape from red-hot stand-pipes, being converted into gas during their progress. In order to prevent accumulations of carbon in the mouths of the pipes, a tubular cutter shown at $M$ is employed. At $N$ are the saddle-pipes, provided with steam-pipes $O$ for conducting steam through them to cleanse them. In order to remove the fine particles of carbon which the gas contains, it is caused to bubble through the liquid which seals the dip-pipes $P$ in the hydraulic main. To this end a ring of holes is made near the end of the dip-pipe, and the main is filled with water and gelatine or other gummy substance until the fluid level is above the holes. The gas forces its way down through this liquid and escapes in jets from the orifices. By means of buckets arranged under the ends of the pipes, as shown at $Q$, Fig. 2024, the holes may be closed, and the gas generated in one retort may be turned into another.

*Oil-Gas.*—An apparatus for obtaining gas by the distillation of oil is represented in Fig. 2025. To accelerate the evolution of gas, and shorten the time which the gas already produced has to remain in the red-hot vessel, the retort $a$ is filled with bricks, or lumps of coke, which extend the red-hot surface very materially. The second cylinder $b$ serves both as reservoir and hydraulic main at the same time, and, with this object in view, $a$ and $b$ are connected in two places, $d$ and $g$. Oil flows from a large cistern above the apparatus in a constant stream through the tube $c$ to $b$, and $b$ is thus kept filled up to a certain level. From $b$ the oil descends through $e$ to $a$, is converted into gas and tar, and returns through $d$ to $b$. The tube $d$ makes a short bend, and just enters below the fluid-level in $b$, so that the vapors of the decomposed oil must constantly pass through the reservoir of oil, and deposit their tar. The retort $a$ is, therefore, constantly supplied, not only with oil, but with a mixture of oil and tar, in such a manner that all the condensed products return to the retort together with a fresh quantity of oil, until they are completely converted into gas. If the experiment is made in a long tube, inclined at the hinder part, while the front is kept cool, hardly any tar will be produced. The gas which collects above the oil in $b$ passes on through the tube $g$. As the objections raised in the case of coal-gas do not here occur, cast-iron retorts are solely used in oil-gas works, with the same firing in other respects, $r$ being the grate. According to trustworthy statements, 1 cubic foot (= about 4 gallons) of oil produces 600 to 700 cubic feet of gas, which is equivalent to from 90 to 96 per cent. by weight; the remainder is carbon, which is deposited between the coke or bricks, and some unavoidable loss. The production of oil-gas is a continuous process, and thus differs from the distillation of coal. The retorts only require opening now and then, for the removal of the deposit of graphite. Vapors of the same composition and properties are found in oil-gas as in coal-gas.



2025.

*Table showing Products of Distillation of Oils.*

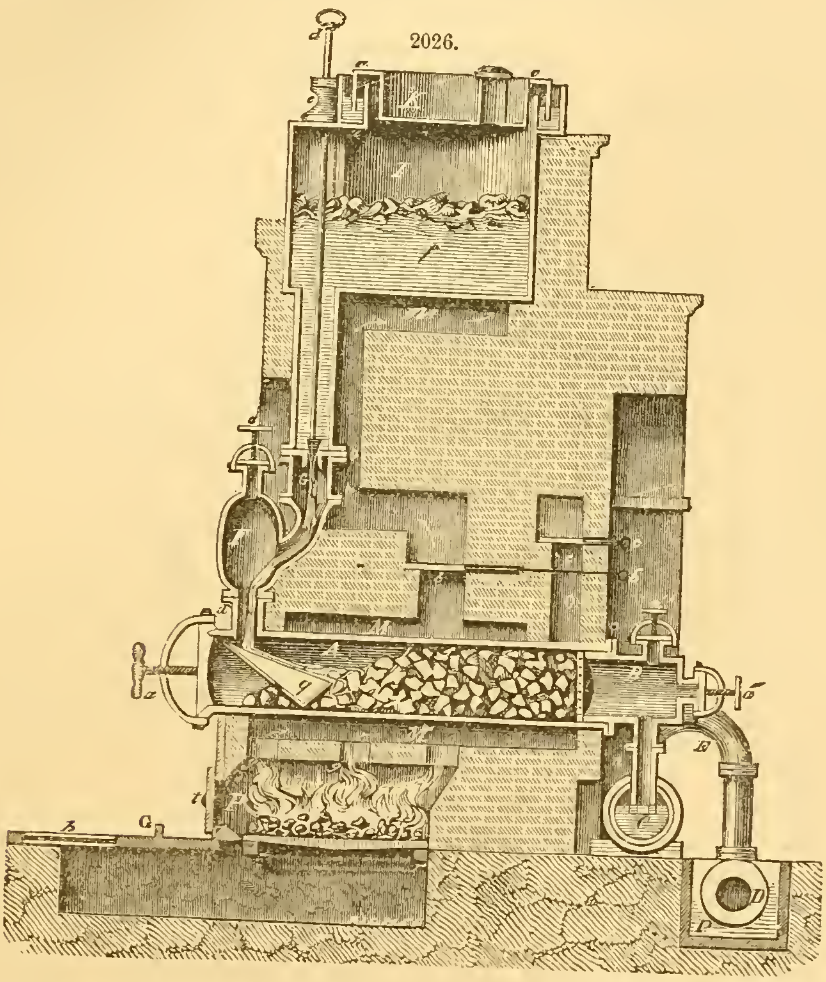
| SUBSTANCES DISTILLED. | TEMPERATURE OF THE DISTILLATION. | Specific Gravity of the Gas. | Absorbed by Chlorine. | Light Carburetted Hydrogen. | Carbonic Oxide. | Hydrogen. | Nitrogen. |
|---|---|---|---|---|---|---|---|
| | | | In 100 parts of Illuminating Gas. | | | | |
| Oil........ | Bright red heat............... | 0.464 | 6 | 28.2 | 14.1 | 45.1 | 6.6 |
| | " " " ............ | 0.590 | 19 | 32.4 | 12.2 | 32.4 | 4 |
| | Lowest possible temperature.. | 0.758 | 22.5 | 50.3 | 15.5 | 7.7 | 4 |
| Train-oil..... | Low red heat................ | 0.906 | 38 | 46.5 | 9.5 | 3 | 3 |

*Rosin-Gas.*—If rosin (colophony) were usually fluid, instead of being solid, there would be no difference between the mode of obtaining gas from it and that practised in the oil-gas manufacture. As this, however, is not the case, it becomes necessary to render the rosin fluid by some suitable means, that it may be easily supplied to the retort. The volatile oil from tar is frequently used for this purpose.

The flame from the retort fire, before escaping by the chimney, is caused to heat up a vessel containing rosin. As this melts, it trickles through a sieve into the second division of the vessel, leaving the impurities and the solid portion behind, where it is mixed with an equal part of the oil of rosin (tar). Thus a solution which will no longer solidify is obtained, and with it the retort is supplied, as with oil in the former case. When the gas has parted with its condensible vapors in the coolers, it is in a fit state for consumption, no further purification being required, as is likewise the case with oil-gas.

One of the best arrangements for rosin-gas, and which has stood the test of practice, is that which has been extensively carried out by Chaussenot, and is shown in Fig. 2026; the rosin is here melted by itself, and the oil of tar collected and disposed of as a secondary product.

2026.



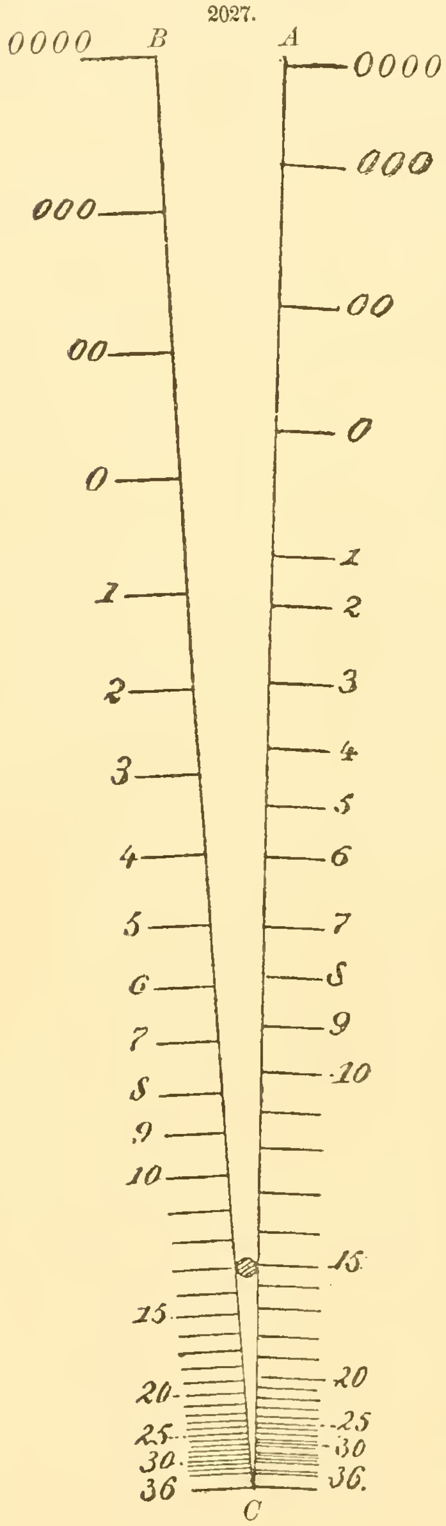
*Gas from Soap-Water.*—Few cases are adapted to give so favorable an idea of the practical value of gas illumination as the process carried out at the works of Houzeau Muiron, at Rheims, where very good gas is obtained from refuse which previously cost something to throw away, and which now is a source of profit to the manufacturer. This refuse is the soap-water in which woolen stuffs have been freed from fat. Besides the unchanged fat with which those goods are charged as they come from the loom, the soap-water contains a solution of oleate and stearate of soda, and compounds of the same acid with lime in suspended flakes, and, lastly, animal matters extracted from the wool. From all parts of the town the soap-water is collected, and brought to the reservoirs of the works, where 300 cwts. at a time are treated with 2 per cent. of sulphuric acid (or twice as much hydrochloric), mixed with equal parts of water. After the lapse of 12 to 18 hours, complete coagulation is effected. The water contains Glauber's salt (sulphate of soda) in solution; a little gypsum is formed at the same time, and an impure gray fatty matter rises to the surface. This consists of the fatty acids, oil, and animal matter, with much water; the greater part of the latter has already been mechanically separated, and the remainder is removed by melting in copper vessels; the contents are then drawn off into a second boiler containing some sulphuric acid, to effect clarification. The filtration which follows affords a clear oil, and this gives with crude soda (containing sulphuret of sodium) a very tolerable soap, while sulphuret of iron separates, together with a black solid residue, containing much fat for distillation in the gas-retorts. The process of distillation is like that practised with rosin: the tar produced the first day is used on the morrow to dissolve and render fluid the solid residue, and so on.

*Gas from Animal Matter.*—In the distillation of animal matters, bones, flesh, etc., as it has long

been practised for the production of bone-charcoal and bone-black, tar (stinking oil, Dippel's animal oil) and gases are generated. The illuminating power of the latter has attracted the attention of manufacturers. Seguin, in particular, has carried on the process on a large scale, making use of the gases. The material—for instance, the flesh of dead animals—contains 60 per cent. of water, which must be removed by drying before being placed in the retorts, and the latter should be kept at a cherry-red heat. The sulphur (a constituent of albumen, fibrine, etc.) is chiefly found in the gas as sulphuret of carbon, the nitrogen of the flesh as carbonate of ammonia. After being properly cooled, the gas is first passed through a solution of chloride of calcium, where carbonate of lime and sal ammoniac are formed, and thence through tubes containing lumps of sulphur, which condense the sulphuret of carbon to the fluid state, and dissolve in it. The latter would be converted in the flame into sulphurous acid and carbonic oxide.

A process is employed to convert the gases arising from rendering-tanks into a good illuminating gas, as follows: The gas proceeding from the tank is made to pass through a coil which is kept cool by means of a flow of water; the vapor of water is condensed and runs off, while the gas passes on through pipes to the bottom of a large tank containing gasoline, through which it bubbles, enriching itself with the hydrocarbon, and then passes on to the holder, ready for use. H. A. M., Jr.

2027.




GAS-ENGINE. See ENGINES, GAS AND BINARY VAPOR.

GAS-FURNACE. See FURNACES, GLASS-MAKING, and IRON-MAKING PROCESSES.

GAS-LIGHTER, ELECTRIC. See ELECTRIC GAS-LIGHTER.

GASOMETER. See GAS, ILLUMINATING, APPARATUS FOR MANUFACTURE OF.

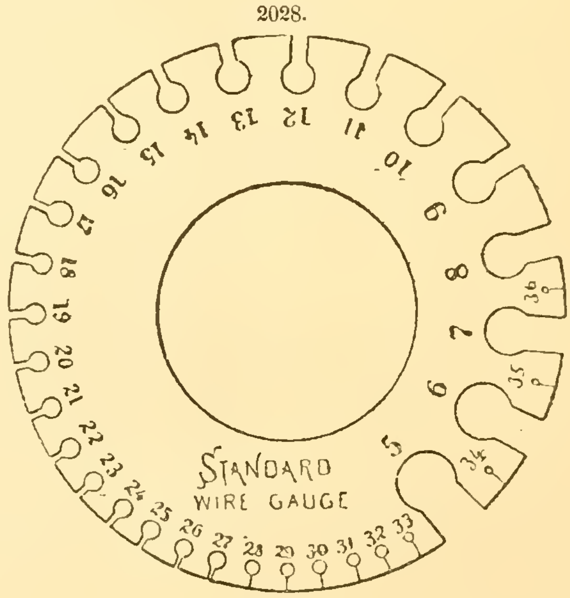
GAS-STOVE. See STOVES AND HEATING FURNACES.

GATLING GUN. See ORDNANCE (MACHINE GUNS).

GAUGE, GUNPOWDER. See EXPLOSIVES.

GAUGE, WIRE. The American standard wire-gauge is a production of Messrs. J. R. Brown & Sharpe, the object

2028.

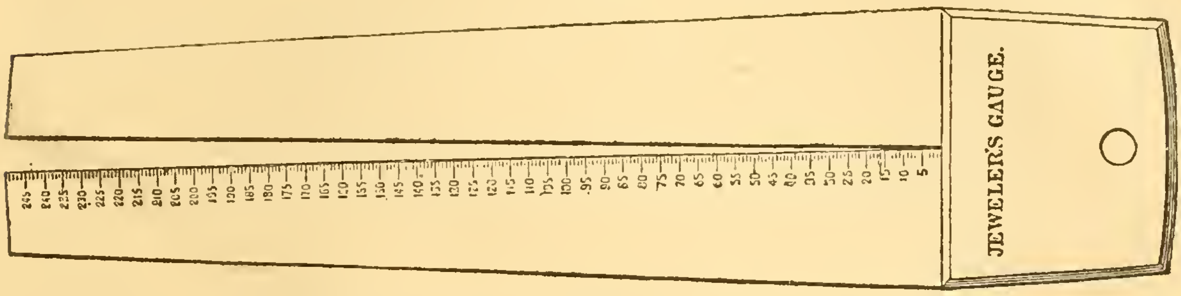



being to introduce greater uniformity in the progression of the sizes. This will be clearly understood by reference to the diagram shown in Fig. 2027, in which the two lines *A C* and *B C*, meeting at *C*, represent the opening of an angular wire-gauge. The divisions on the line *A C* show the sizes of wire by the common gauge; those on the line *B C*, the sizes by the new American standard. Wire to be measured by such a gauge is passed into the angular opening until it touches on both sides, the line of division at the point of contact denoting the size by wire-gauge number. Thus No. 13 by the old gauge is No. 15 by the new. The standard gauge, as adopted by the sheet-brass manufacturers in the United States, is shown in Fig. 2028.

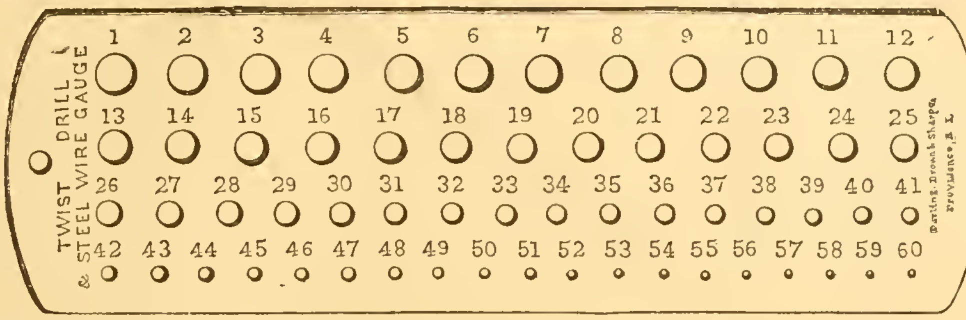
In Fig. 2029 is shown a jeweler's wire-gauge. One edge of the angular slot is graduated into 250 parts, and figured to give the size in thousandths of an inch. For example, a size of wire which, passed down half way in the slot, will stop opposite 125, is $\frac{125}{1000}$ of an inch in diameter. The angular slot has no sharp edge to injure the stock gauged.

Fig. 2030 represents a twist-drill and steel-wire gauge by the same makers.

2029.




2030.




The difference between the two gauges, known respectively as the Birmingham or English and the American, is shown in the table below.

*Table of Birmingham and American Wire-Gauges.*

| NO. OF WIRE-GAUGE. | AMERICAN OR NEW STANDARD. | | BIRMINGHAM OR OLD STANDARD. | | NO. OF WIRE-GAUGE. | AMERICAN OR NEW STANDARD. | | BIRMINGHAM OR OLD STANDARD. | |
|---|---|---|---|---|---|---|---|---|---|
| | Size of each Number in Decimal Parts of an Inch. | Difference between consecutive Numbers in Decimal Parts of an Inch. | Size of each Number in Decimal Parts of an Inch. | Difference between consecutive Numbers in Decimal Parts of an Inch. | | Size of each Number in Decimal Parts of an Inch. | Difference between consecutive Numbers in Decimal Parts of an Inch. | Size of each Number in Decimal Parts of an Inch. | Difference between consecutive Numbers in Decimal Parts of an Inch. |
| 0000 | 0.460 | ....... | 0.454 | ..... | 19 | 0.03589 | 0.00441 | 0.042 | 0.007 |
| 000 | 0.40964 | 0.05036 | 0.425 | 0.029 | 20 | 0.03196 | 0.00393 | 0.035 | 0.007 |
| 00 | 0.36480 | 0.04484 | 0.380 | 0.045 | 21 | 0.02846 | 0.00350 | 0.032 | 0.003 |
| 0 | 0.32495 | 0.03994 | 0.340 | 0.040 | 22 | 0.02525 | 0.00311 | 0.028 | 0.004 |
| 1 | 0.28930 | 0.03556 | 0.300 | 0.040 | 23 | 0.02257 | 0.00278 | 0.025 | 0.003 |
| 2 | 0.25763 | 0.03167 | 0.284 | 0.016 | 24 | 0.0201 | 0.00247 | 0.022 | 0.003 |
| 3 | 0.22942 | 0.02821 | 0.259 | 0.025 | 25 | 0.0179 | 0.00220 | 0.020 | 0.002 |
| 4 | 0.20431 | 0.02511 | 0.238 | 0.021 | 26 | 0.01594 | 0.00196 | 0.018 | 0.002 |
| 5 | 0.18194 | 0.02237 | 0.220 | 0.018 | 27 | 0.01419 | 0.00174 | 0.016 | 0.002 |
| 6 | 0.16202 | 0.01992 | 0.203 | 0.017 | 28 | 0.01264 | 0.00155 | 0.014 | 0.002 |
| 7 | 0.14428 | 0.01774 | 0.180 | 0.023 | 29 | 0.01126 | 0.00138 | 0.013 | 0.001 |
| 8 | 0.12849 | 0.01579 | 0.165 | 0.015 | 30 | 0.01002 | 0.00123 | 0.012 | 0.001 |
| 9 | 0.11443 | 0.01406 | 0.148 | 0.017 | 31 | 0.00893 | 0.00110 | 0.010 | 0.002 |
| 10 | 0.10189 | 0.01254 | 0.134 | 0.014 | 32 | 0.00795 | 0.00098 | 0.009 | 0.001 |
| 11 | 0.09074 | 0.01105 | 0.120 | 0.014 | 33 | 0.00708 | 0.00087 | 0.008 | 0.001 |
| 12 | 0.08081 | 0.00993 | 0.109 | 0.011 | 34 | 0.0063 | 0.00078 | 0.007 | 0.001 |
| 13 | 0.07196 | 0.00885 | 0.095 | 0.014 | 35 | 0.00561 | 0.00069 | 0.005 | 0.002 |
| 14 | 0.06408 | 0.00788 | 0.083 | 0.012 | 36 | 0.005 | 0.00061 | 0.004 | 0.001 |
| 15 | 0.05707 | 0.00702 | 0.072 | 0.011 | 37 | 0.00445 | 0.00055 | ..... | ..... |
| 16 | 0.05082 | 0.00625 | 0.065 | 0.007 | 38 | 0.00396 | 0.00049 | ..... | ..... |
| 17 | 0.04526 | 0.00556 | 0.058 | 0.007 | 39 | 0.00353 | 0.00043 | ..... | ..... |
| 18 | 0.0403 | 0.00495 | 0.049 | 0.009 | 40 | 0.00314 | 0.00039 | ..... | ..... |

*Dimensions of Sizes of Gauge, in Decimal Parts of an Inch.*

| NO. | Size of Number in Decimals. | NO. | Size of Number in Decimals. | NO. | Size of Number in Decimals. | NO. | Size of Number in Decimals. | NO. | Size of Number in Decimals. | NO. | Size of Number in Decimals. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | .227 | 11 | .188 | 21 | .157 | 31 | .120 | 41 | .095 | 51 | .066 |
| 2 | .219 | 12 | .185 | 22 | .155 | 32 | .115 | 42 | .092 | 52 | .063 |
| 3 | .212 | 13 | .182 | 23 | .153 | 33 | .112 | 43 | .088 | 53 | .058 |
| 4 | .207 | 14 | .180 | 24 | .151 | 34 | .110 | 44 | .085 | 54 | .055 |
| 5 | .204 | 15 | .178 | 25 | .148 | 35 | .108 | 45 | .081 | 55 | .050 |
| 6 | .201 | 16 | .175 | 26 | .146 | 36 | .106 | 46 | .079 | 56 | .045 |
| 7 | .199 | 17 | .172 | 27 | .143 | 37 | .103 | 47 | .077 | 57 | .042 |
| 8 | .197 | 18 | .168 | 28 | .139 | 38 | .101 | 48 | .075 | 58 | .041 |
| 9 | .194 | 19 | .164 | 29 | .134 | 39 | .099 | 49 | .072 | 59 | .040 |
| 10 | .191 | 20 | .161 | 30 | .127 | 40 | .097 | 50 | .069 | 60 | .039 |

Solid cylindrical tools are often made of steel wire, drawn to gauge and to great accuracy of diametrical size. There is, however, a slight degree of variation due to the wear of drawing-dies. In the table below will be found the gauge numbers and the sizes in decimal parts of an inch of the Stubs wire. The first column is the size according to the Stubs wire-gauge; the second is the size in decimal parts of an inch, as given by Mr. Stubs; and the third column represents the average sizes obtained from actual measurements of the wire, taken during a period of several years by the Morse Twist-Drill and Machine Company.

*Table showing Diameter of Stubs's Steel Wire, in Fractional Parts of an Inch.*

| NO. OF STUBS'S WIRE-GAUGE. | Stubs's Dimensions. | Measurement by Morse Twist-Drill and Machine Co. | NO. OF STUBS'S WIRE-GAUGE. | Stubs's Dimensions. | Measurement by Morse Twist-Drill and Machine Co. | NO. OF STUBS'S WIRE-GAUGE. | Stubs's Dimensions. | Measurement by Morse Twist-Drill and Machine Co. |
|---|---|---|---|---|---|---|---|---|
| 1 | .227 | .228 | 23 | .153 | .154 | 45 | .081 | .082 |
| 2 | .219 | .221 | 24 | .151 | .152 | 46 | .079 | .080 |
| 3 | .212 | .213 | 25 | .148 | .150 | 47 | .077 | .079 |
| 4 | .207 | .209 | 26 | .146 | .148 | 48 | .075 | .076 |
| 5 | .204 | .206 | 27 | .143 | .145 | 49 | .072 | .073 |
| 6 | .201 | .204 | 28 | .139 | .141 | 50 | .069 | .070 |
| 7 | .199 | .201 | 29 | .134 | .136 | 51 | .066 | .067 |
| 8 | .197 | .199 | 30 | .127 | .129 | 52 | .063 | .064 |
| 9 | .194 | .196 | 31 | .120 | .120 | 53 | .058 | .060 |
| 10 | .191 | .194 | 32 | .115 | .116 | 54 | .055 | .057 |
| 11 | .188 | .191 | 33 | .112 | .113 | 55 | .050 | .052 |
| 12 | .185 | .188 | 34 | .110 | .111 | 56 | .045 | .047 |
| 13 | .182 | .185 | 35 | .108 | .110 | 57 | .042 | .044 |
| 14 | .180 | .182 | 36 | .106 | .106 | 58 | .041 | .042 |
| 15 | .178 | .180 | 37 | .103 | 104 | 59 | .040 | .041 |
| 16 | .175 | .177 | 38 | .101 | .101 | 60 | .039 | .040 |
| 17 | .172 | .173 | 39 | .099 | .100 | 61 | .038 | .039 |
| 18 | .168 | .170 | 40 | .097 | .098 | 62 | .037 | .038 |
| 19 | .164 | .166 | 41 | .095 | .096 | 63 | .036 | .037 |
| 20 | .161 | .161 | 42 | .092 | .094 | 64 | .035 | .036 |
| 21 | .157 | .159 | 43 | .088 | .089 | 65 | .033 | .035 |
| 22 | .155 | .156 | 44 | .085 | .086 | | | |

*Table showing Letter Sizes of Stubs's Wire.*

| | | | | | |
|---|---|---|---|---|---|
| A ....... .234 | F........ .257 | K....... .281 | O ....... .316 | S........ .348 | W....... .386 |
| B ....... .238 | G....... .261 | L........ .290 | P ....... .323 | T ....... .358 | X....... .397 |
| C........ .242 | H....... .266 | M....... .295 | Q....... .332 | U....... .368 | Y....... .404 |
| D....... .246 | I........ .272 | N....... .302 | R ....... .339 | V ....... .377 | Z........ .413 |
| E....... .250 | J........ .277 | | | | |

*Table showing Whitworth's Standard Wire-Gauge, compared with corresponding Numbers of various other Wire-Gauges.*

| Value of each Number in Decimals. | Number of Whitworth's Standard Gauge. | NUMBERS CORRESPONDING TO WHITWORTH'S GAUGE. | | | | | Value of each Number in Decimals. | Number of Whitworth's Standard Gauge. | NUMBERS CORRESPONDING TO WHITWORTH'S GAUGE. | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Birmingham Wire-Guage. | Lancashire Wire-Gauge. | Old Metal Wire-Gauge. | Needle-wire Gauge. | Music-wire Gauge. | | | Birmingham Wire-Gauge. | Lancashire Wire-Gauge. | Old Metal Wire-Gauge. | Needle-wire Gauge. | Music-wire Gauge. |
| .001 | 1 | .. | .. | .. | .. | .. | .050 | 50 | 18 | 54 | 17* | .. | .. |
| .002 | 2 | .. | .. | .. | .. | .. | .055 | 55 | .. | 52** | 18 | .. | .. |
| .003 | 3 | .. | .. | .. | .. | .. | .060 | 60 | 17* | 51 | 19 | .. | .. |
| .004 | 4 | 36 | .. | 1 | 19 | .. | .065 | 65 | 16 | 49* | 21* | .. | .. |
| .005 | 5 | 35 | .. | 2 | 18 | .. | .070 | 70 | 15* | 47* | 22* | .. | .. |
| .006 | 6 | .. | .. | .. | .. | .. | .075 | 75 | .. | 45 | 24* | .. | .. |
| .007 | 7 | 34 | .. | .. | 17 | .. | .080 | 80 | .. | 43* | .. | .. | .. |
| .008 | 8 | 33 | .. | .. | 16 | .. | .085 | 85 | 14* | 42* | .. | .. | .. |
| .009 | 9 | 32 | .. | .. | 15 | .. | .090 | 90 | .. | 41 | 25 | .. | .. |
| .010 | 10 | 31 | .. | .. | 14 | .. | .095 | 95 | 13 | 38 | 26** | .. | .. |
| .011 | 11 | .. | .. | .. | .. | .. | .100 | 100 | .. | 34 | 27** | .. | .. |
| .012 | 12 | 30 | 80 | .. | .. | .. | .110 | 110 | 12 | 31* | 28 | .. | .. |
| .013 | 13 | 29 | 79 | .. | 12 | .. | .120 | 120 | 11 | 29 | 31* | .. | .. |
| .014 | 14 | 28 | 78 | | 11 | .. | .135 | 135 | 10 | 23** | 34* | .. | .. |
| .015 | 15 | .. | 77 | .. | .. | .. | .150 | 150 | 9* | 19 | 36* | .. | .. |
| .016 | 16 | 27 | .. | .. | .. | .. | .165 | 165 | 8 | 13** | .. | .. | .. |
| .017 | 17 | .. | 76 | .. | .. | .. | .180 | 180 | 7 | 5** | .. | .. | .. |
| .018 | 18 | 26 | .. | .. | 9 | 6 | .200 | 200 | 6** | 2 | .. | .. | .. |
| .019 | 19 | .. | 75 | .. | 8 | 7 | .220 | 220 | 5 | C* | .. | .. | .. |
| .020 | 20 | 25 | 74 | .. | 7 | 8 | .240 | 240 | 4* | G | .. | .. | .. |
| .022 | 22 | 24 | 72 | 10 | 6 | 10 | .260 | 260 | 3 | K | .. | .. | .. |
| .024 | 24 | 23* | 71 | .. | .. | 12 | .280 | 280 | 2* | N* | .. | .. | .. |
| .026 | 26 | .. | 70 | 11 | 5 | 13 | .300 | 300 | 1 | P* | .. | .. | .. |
| .028 | 28 | 22 | 68 | .. | .. | 14 | .325 | 325 | .. | S* | .. | .. | .. |
| .030 | 30 | .. | 66 | .. | 4 | 15 | .350 | 350 | .. | V* | .. | .. | .. |
| .032 | 32 | 21 | 64 | 12 | .. | 16 | .375 | 375 | 00** | X* | .. | .. | .. |
| .034 | 34 | .. | 62 | 13 | 3 | 17 | .400 | 400 | .. | .. | .. | .. | .. |
| .036 | 36 | 20 | 61 | .. | .. | 18 | .425 | 425 | 000** | .. | .. | .. | .. |
| .038 | 38 | .. | 59 | 14 | 2* | 19 | .450 | 450 | 0000** | .. | .. | .. | .. |
| .040 | 40 | 19* | 56 | 15* | 1 | 20* | .475 | 475 | .. | .. | .. | . | .. |
| .045 | 45 | .. | 54 | 16 | .. | .. | .500 | 500 | .. | .. | .. | .. | .. |

*Note.*—The numbers of the Birmingham and other gauges correspond exactly, or within .001 of an inch, to the numbers on the Whitworth wire-gauge, except those marked *, which are within .002, and those marked **, which are beyond .002 of an inch. Below .001, one thousand means .002, two thousand parts of an inch.

*French Wire-Gauge.*—

*Table showing the French Limoges Gauge (Jauge de Limoges).*

| NUMBER. | Diameter. | | NUMBER. | Diameter. | | NUMBER. | Diameter. | |
|---|---|---|---|---|---|---|---|---|
| | Millimetre. | Inch. | | Millimetre. | Inch. | | Millimetre. | Inch. |
| 0 | .39 | .0154 | 9 | 1.35 | .0532 | 17 | 2.84 | .112 |
| 1 | .45 | .0177 | 10 | 1.46 | .0575 | 18 | 3.40 | .134 |
| 2 | .56 | .0221 | 11 | 1.68 | .0661 | 19 | 3.95 | .156 |
| 3 | .67 | .0264 | 12 | 1.80 | .0706 | 20 | 4.50 | .177 |
| 4 | .79 | .0311 | 13 | 1.91 | .0752 | 21 | 5.10 | .201 |
| 5 | .90 | .0354 | 14 | 2.02 | .0795 | 22 | 5.65 | .222 |
| 6 | 1.01 | .0398 | 15 | 2.14 | .0843 | 23 | 6.20 | .244 |
| 7 | 1.12 | .0441 | 16 | 2.25 | .0886 | 24 | 6.80 | .268 |
| 8 | 1.24 | .0488 | | | | | | |

J. R. (in part).

GAUGES, MECHANICAL. Standard gauging implements were introduced about the year 1840, by the celebrated Swiss engineer, John G. Bodmer. He not only employed gauges in his works to secure duplicate dimensions, but also invented and put in use many other reforms in manipulation; among these may be mentioned the decimal or metrical division of measures, a system of detail drawings classified by symbols, the mode of calculating wheels by diametric pitch, with many other things which characterize the best modern practice.

The importance of standard dimensions, and the effect which a system of gauging may have in the construction of machines, will be a matter of some difficulty for a learner to understand. The interchangeability of parts, which is the immediate object in employing gauges, is plain enough, and some of the advantages are at once apparent; yet the ultimate effects of such a system extend much farther than will at first be supposed. The division of labor, that system upon which we may say our great industrial interests are founded, is in machine-fitting promoted in a wonderful degree by the use of gauging implements. If standard dimensions can be maintained, it is easy to see that the parts of a machine can be constructed by different workmen, or in different shops, and these parts when assembled all fit together, without that tedious and uncertain plan of try-fitting which was once generally practised.

The gauging system has been no little retarded by a selfish and mistaken opinion that an engineering establishment may maintain peculiar standards of its own; in fact, relics of this spirit are yet to be met with in old machines, where the pitch of screw-threads has been made to fractional parts of an inch, so that engineers other than the original makers could not well perform repairing or replace broken parts. One of the effects of employing gauges in machine-fitting is to inspire confidence in workmen. Instead of a fit being regarded as a mysterious result, more the work of chance than design, men accustomed to gauges come to regard precision as something both attainable and indispensable. A learner, after examining a set of well-fitted cylindrical gauges, will form a new conception of what a fit is, and will afterward have a new standard fixed in his mind.

The variation of dimensions which is sensible to the touch at one ten-thousandth part of an inch furnishes an example of how important the human senses are even after the utmost precision attainable by machine action. Pieces may pass beneath the cutters of a milling-machine under conditions which, so far as machinery avails, will produce uniform sizes, yet there is no assurance of the result until the work is felt by gauges. The eye fails to detect variations in size, even by comparison, long before we reach the necessary precision in common fitting. Even by comparison with figured scales or measuring with rules, the difference between a proper and a spoiled fit is not discernible by sight. Many of the most accurate measurements are, however, performed by sight, with vernier calipers for example, the variation being multiplied hundreds or thousands of times by mechanism, until the least differences can be readily seen. (See CALIPERS.) In multiplying the variations of a measuring implement by mechanism, it is obvious that movable joints must be employed; it is also obvious that no positive joint, whether cylindrical or flat, could be so accurately fitted as to transmit such slight movement as occurs in gauging or measuring. This difficulty is in most measuring instruments overcome by employing a principle not before alluded to, but common in many machines, that of elastic compensation. A pair of spring calipers will illustrate this principle. The points are always steady, because the spring acting continually in one direction compensates the loose play that may be in the screw. In a train of tooth-wheels there is always more or less play between the teeth; and unless the wheels always revolve in one direction, and have some constant resistance offered to their motion, "backlash" or irregular movement will take place; but if there is some constant and uniform resistance, such as a spring would impart, a train of wheels will transmit the slightest motion throughout.

The extreme nicety with which gauging implements are fitted seems at first thought to be unnecessary; but it must be remembered that a cylindrical joint in ordinary machine-fitting involves a precision almost beyond the sense of feeling, and that any sensible variation in turning gauges is enough to spoil a fit. Opposed to the maintenance of standard dimensions are the variations in size due to temperature. This difficulty applies alike to gauging implements and to parts that are to be tested; yet in this, as in nearly every phenomenon connected with matter, we have succeeded in turning it to some useful purpose. Bands of iron, such as the tires of wheels when heated, can

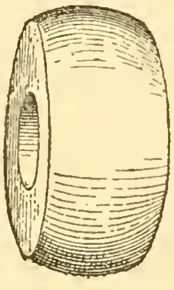
be shrunk on, and a compressive force and security attained which would be impossible by forcing the parts together both at the same temperature. Shrinking has, however, been almost entirely abandoned for such joints as can be accurately fitted.

The foregoing remarks are taken from Richards's "Workshop Manipulation." The reader will find examples illustrating their practical application under FIRE-ARMS, MANUFACTURE OF, SEWING-MACHINES, and in the various articles describing the construction of machine-tools. Sir Joseph Whitworth, in an address delivered before the Institution of Mechanical Engineers, Manchester, in 1857, referring to the subject of accurate gauging, says:

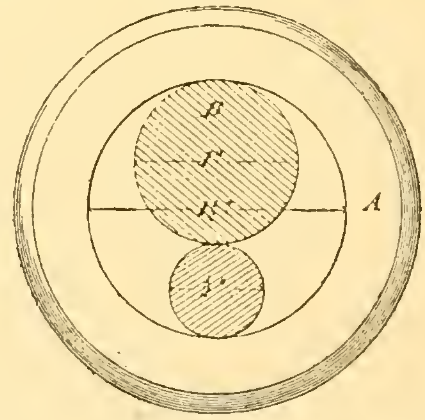
"As an illustration of the importance of very small differences of size, I have brought an internal gauge having a cylindrical aperture .5770 inch diameter, and two external gauges or solid cylinders, one being .5769 inch and the other .5770 inch diameter. The latter is $\frac{1}{10000}$ of an inch larger than the former, and fits tightly in the internal gauge when both are clean and dry; while the smaller .5769 inch gauge is so loose in it as to appear not to fit at all. These gauges are finished with great care, and are made true after being case-hardened. They are so hard that nothing but the diamond will cut them, except the grinding process to which they have been subjected. The effect of applying a drop of fine oil to the surfaces of these gauges is very remarkable. It will be observed that the fit of the larger cylinder becomes more easy, while that of the smaller becomes more tight. These results show the necessity of proper lubrication. In the case of the external gauge .5770 inch diameter, the external and internal gauges are so near in size that the one does not go through the other when dry, and if pressed in there would be danger of the surface particles of the one becoming imbedded in or among those of the other, which I have seen happen, and then no amount of force will separate them; but with a small quantity of oil on their surfaces they move easily and smoothly. In the case of the external gauge .5769 inch diameter, which is $\frac{1}{10000}$ of an inch smaller in diameter than the internal gauge, a space of half that quantity is left between the surfaces; this becomes filled with the oil, and hence the tighter fitting which is experienced. It is therefore obvious both to the eye and the touch, that the difference between these two cylinders of $\frac{1}{10000}$ of an inch is an appreciable and important quantity; and what is now required is a method which shall express systematically and without confusion a scale applicable to such minute differences and measurements: it should be based on a uniform principle which will accustom the workman to speak of his measures as aggregates of very small differences; and when a good workman becomes familiar with such sizes as $\frac{1}{1000}$ and $\frac{1}{10000}$ of an inch, he will not rest satisfied until he can work with corresponding accuracy. He will also be able to judge of their effect under different circumstances, and know how much to allow in the fitting parts of a machine, according to their relative importance and the treatment they are likely to receive at the hands of the attendant. For instance, the cylinder of the moving headstock of a lathe requires as good a fit as possible; but in practice it is found that the cylinder must be .0005 inch or $\frac{1}{2000}$ of an inch too small, because it frequently happens that machinery is not kept in a proper state of cleanliness, or from motives of false economy is lubricated with bad oil. These are two evils which are productive of great mischief. The abrasion caused by accumulated dust and grit produces increased wear and tear, and soon injures the surfaces in contact; while bad oil becomes sticky and rancid, and spoils the working of a good fit. And here let me state what I think is the proper definition of a good fit. A tight fit is not necessarily a good one; but when the surfaces are true, and a proper allowance is made in the size of the parts working together, then a good fit is obtained. What constitutes a proper allowance or difference in size depends on the nature of the case, and the treatment which the machinery will meet with. In machinery supplied to establishments using rape oil there must be greater allowance and looseness in the fits than would be requisite if better oil, as sperm oil, were used. I need scarcely say how much more advisable it is to have the more accurate fit and use the best oil, than to have a loose fit and use the inferior oil which, causing more friction, consumes greater power. The deterioration of templets or patterns of size, from their becoming worn or altered in process of time, is productive of great inconvenience, as many of us perhaps have experienced. For when an original standard was thus altered, it was irretrievably lost, because there was no means of ascertaining and recording the exact measure. It is of great importance to the manufacturer who makes parts of machines in large quan-

2031.

2032.



2033.

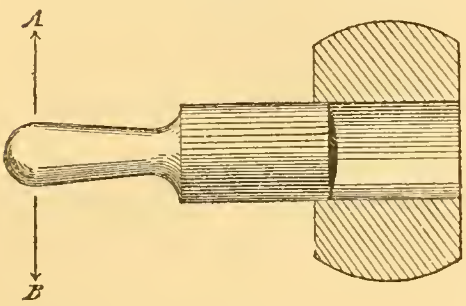



tities to have the means of referring to an accurate fixed measure; it will enable him to reproduce at any time a facsimile of what he has once made, and so preserve a system of sizes of the fitting parts unaltered. The greatest care should be taken to make standards of size correctly at first, and to preserve them unaltered. Errors in the standards are not only propagated in the copies, but are

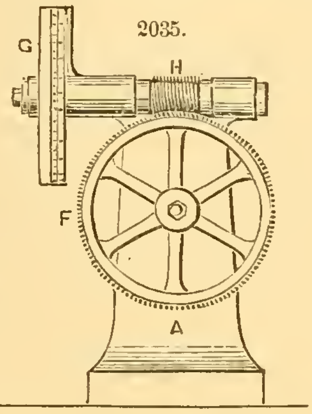
superadded to the errors in the workmanship which will occur in the course of manufacture; and this is especially likely to occur in cases where one manufacturer supplies parts of machines for the use of another."

Forms of Gauges.—*Standard Gauges.*—The gauges used as standards for male and female cylindrical forms are usually after the pattern shown in Figs. 2031 and 2032. They are made of steel, hardened and ground to size, the grinding process being so delicately performed as to leave a polish. In testing such gauges, the heat imparted to them by holding them for any length of time in the hand will cause a perceptible difference in the size; hence, to insure the greatest practical accu-

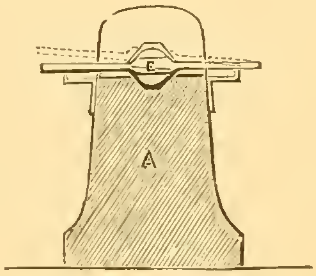
2034.




2035.

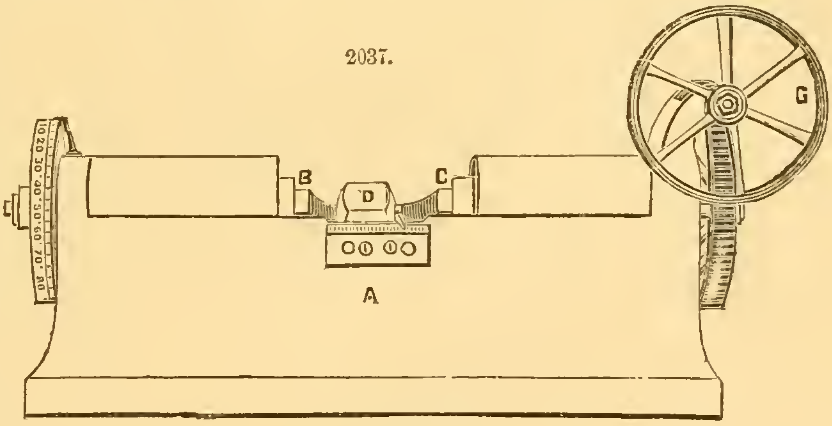



2036.



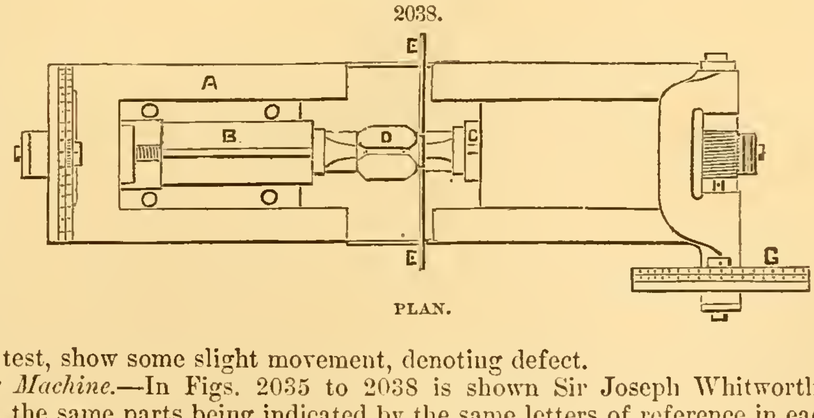

racy, it is necessary to test the whole set at an equal temperature. As a test of accuracy, we may take a female gauge and place therein two or three male gauges, whose diameters added together will equal that of the female. Thus, in Fig. 2033, the size of the female gauge *A* being $1\frac{1}{2}$ inch, that of the male *B* may be 1 inch, and that of *C* half an inch, and the two together should just fit the female. On the other hand, were we to use, instead of *B* and *C*, two males seven-eighths and five-eighths inch respectively, they should fit the female; or a half inch, a five-eighths inch, and a three-eighths inch male gauge together should fit the female. By a series of tests of this description, the accuracy of the whole set may be tested; and by judicious combinations a defect in the size of any gauge in the set may be detected. A notable fact with reference to these gauges is that, if we take a male and female of corresponding sizes, and slide the one continuously through the other, it will pass through at a proper fit; but if we arrest the progress of the male and allow it to rest a few moments, it will become fast in the female, and require considerable force to remove it again. The wear of these gauges takes place most rapidly at and near the ends, because it is difficult in using them to keep them in lines true with the bores into which they are tried; and the movement due to the adjustment to line causes abrasion. It is indeed an excellent method of testing to place one in the other to the depth of about one-sixteenth of an inch, as shown in Fig. 2034, and, holding the female firmly, lightly press the male first in the direction of *A* and then of *B*. There are few gauges which will not, under such a test, show some slight movement, denoting defect.

2037.




GENERAL VIEW.

2038.



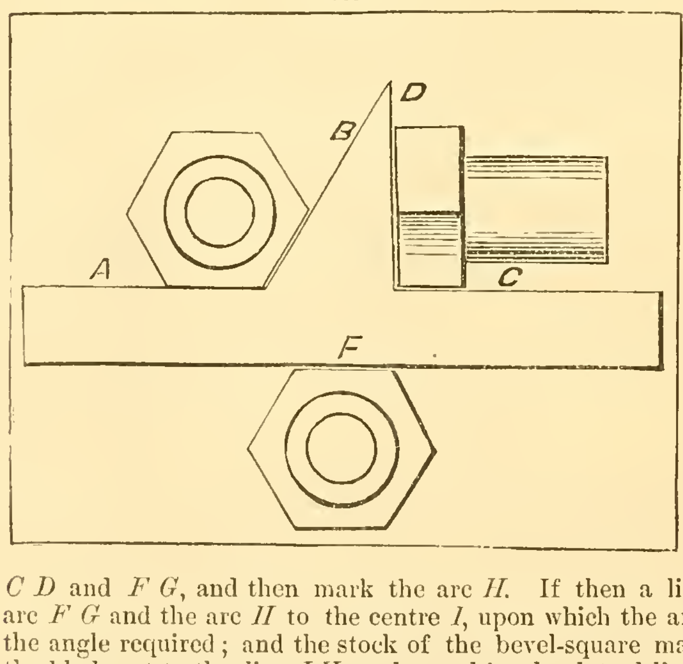

PLAN.

*The Whitworth Measuring Machine.*—In Figs. 2035 to 2038 is shown Sir Joseph Whitworth's millionth-measuring machine, the same parts being indicated by the same letters of reference in each of the views. A standard one-inch bar, *D*, is here shown in position for being measured. A rigid casting, *A*, forms the bed of the machine, and is carried up at each end, forming two headstocks. Running from one of these headstocks to the other is a V-shaped groove, in which the square bars *B* and *C* are laid, and which also receives the other bar, *D*, of which the length is to be tested. The sides of the groove and also those of the bars (which are square in section) are worked up as truly plane as possible, and are kept accurately at right angles to each other, so that, upon whichever side

the bars may rest, they are capable of sliding smoothly and with perfect steadiness in the groove. Their ends also are carefully made square to their sides, and are brought to two planes, one extremity of each in the case of *B* and *C*, and both extremities of *D*, being turned down so as to present circular instead of square faces. Through each headstock runs an accurately pitched micrometer screw, by which *B* and *C* can be driven forward along the groove, as may be seen in the left-hand portion of the plan, in which the saddle, by which *B* is protected and partially concealed when the machine is in use, has been removed. The screw on this side, which has exactly 20 threads to the inch, is driven by a worm-wheel *F* of 200 teeth, into which gears a tangent-screw *H*, having fixed upon its stem the graduated wheel *G*. The circumference of this wheel being also divided into 250 parts, a movement through one division corresponds to a traverse of $\frac{1}{20} \times \frac{1}{200} \times \frac{1}{250}$ = one-millionth of an inch on the part of the bar *C*. Fixed pointers enable the exact distance through which either of the wheels *F* or *G* is moved to be read off, so that we have thus the means of detecting this extremely minute difference in the length of any bars—if, at least, we can fulfill the important condition of causing the micrometer screws to exert a perfectly equal pressure in every case. The arrangement by which this equality of pressure is secured is one of very great simplicity and beauty. Between one extremity of the bar under comparison and the sliding bar a small steel plate with truly plane and parallel sides is introduced. This plate is called the "feeler" or "gravity piece," and its ends *E E* are drawn out so as to rest upon two supports fixed upon the sides of the bed. When little or no pressure is exerted upon the bar *D*, the feeler, if one of its ends be momentarily raised from the support, falls back again by its own weight; when, on the other hand, the pressure is at all considerable, it is either incapable of being raised without violence, or when lifted does not return; the friction, in fact, between its own plane surfaces and those of the bars between which it is placed forming a delicate measure of the pressure to which they are subjected. When this pressure is just sufficient to keep the feeler from falling by its own weight, without interfering with its perfectly free motion when touched, the correct adjustment has been given to the instrument.

Suppose now that a proposed duplicate is to be compared with a standard one-inch bar. The standard *D* and the feeler *E E* are first placed in the positions shown in the figure, contact between them and the sliding bars being nearly established by turning the wheel *F*, after which the final adjustment is given with the wheel *G*. As soon as the feeler on its end, being lifted, remains suspended instead of falling back on its support, the adjustment is known to be complete, and the position of the wheel *G* is accurately noted. Since the new bar is to be an exact copy of the standard, the coarse adjustment-wheel *F* is left untouched, the standard being released by moving the wheel *G* only, which is again adjusted when the duplicate of which the length is to be tested has been laid in the groove. If the position of the wheel then be the same as before, it is evident that the length of the bars is identical; but if not, the exact difference between them is given in millionth parts of an inch by the number of divisions by which the second reading differs from the first; a movement through one of these divisions being sufficient to release the feeler, or again to arrest its fall when the adjustment of *G* is correct. This degree of delicacy will thus be seen greatly to surpass that of the measurements which have been obtained by reading line measures with the aid of powerful microscopes. As an instance of the extreme sensitiveness of machines of this kind, it may be mentioned that the one shown is capable of detecting the expansion in a one-inch bar which is produced by merely touching it for an instant with the finger; and in a larger machine, if due precautions be taken to protect it from dust, moisture, and currents of air, momentary contact of the finger-nail will suffice to produce a measurable amount of expansion in an iron bar 36 inches in length; a space corresponding to half a division on the fine adjustment wheel, or one two-millionths of an inch, having been rendered distinctly perceptible by it.

2039.



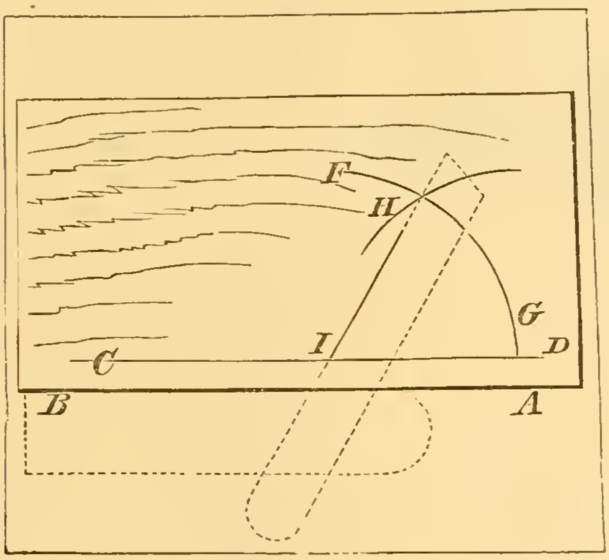

*The Hexagon Gauge.*—This implement is represented in Fig. 2039, applied to a bolt-head, the edges *A B* serving to try the hexagon sides of the head, and *C D* to act as square-edge to the face. The edge *F* is used as a straight-edge. When this gauge is not available, a bevel-square may be set in the following manner: Take a piece of sheet-iron, true on one side and on one edge, and let *A B*, in Fig. 2040, represent the true edge, from which mark with the gauge the line *C D*. Then taking any point, such as *I*, in the line *C D*, as a centre, at a convenient distance describe with a pair of compasses the arc *F G*. Take the compasses, and, without shifting their points at all, rest one point on the intersection of the lines *C D* and *F G*, and then mark the arc *H*. If then a line be drawn from the intersection of the arc *F G* and the arc *H* to the centre *I*, upon which the arc *F G* was struck, the lines *H I*, *I C* form the angle required; and the stock of the bevel-square may be applied to the planed edge *A B*, and the blade set to the line *I H*, as denoted by the dotted lines.

*Machinist's Adjustable Gauge.*—An adjustable gauge is shown in Fig. 2041, in which *A* and *B*

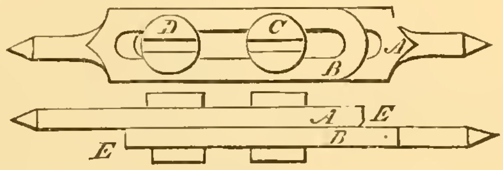
represent two sliding pieces of steel, and *C* and *D* screws and nuts. It is obvious that, when the screws are loosened sufficiently to just let the sliding pieces move by a slight tap, the gauge may be extended by striking the ends *E E*, or either of them, their inside edges being rounded off to prevent them from burring. It is better to set them at first a little below the required size, and to perform the adjustment by opening them, so as not to require to strike the points at all. The points should, however, in any event be tempered to a blue. It is an excellent plan to file away the screw-heads on two sides a little, say one thirty-second of an inch, thus forming a sliding piece under each head to fit into the slot of the gauge, which will prevent the screws from turning when screwed or unscrewed, and in the end save much annoyance.

*Carpenter's Gauge.*—The most convenient form of this tool is shown in Fig. 2042, in which *A* represents the tightening wedge, standing at a right angle to the rod of the gauge. The advantage of this design is that it requires only one hand to work it, inasmuch as the wedge may be loosened

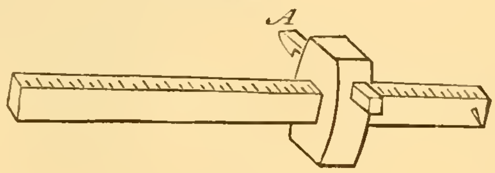
2040.



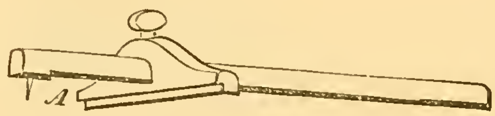

2041.




2042.

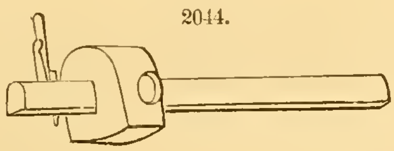



2043.

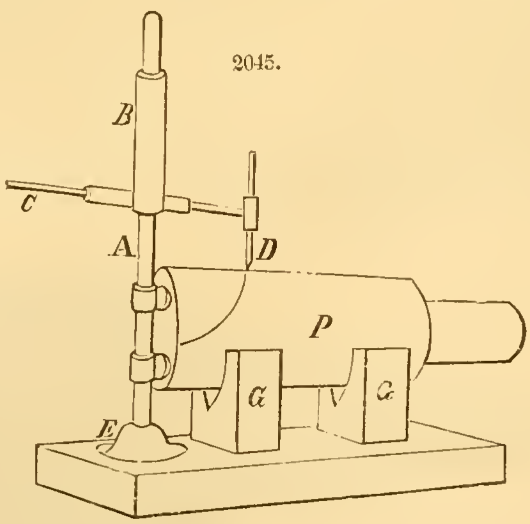



or tightened by striking it, as if it were a hammer, against anything that may happen to lie on the bench. Thus the gauge may be set and adjusted with one hand, while the other is holding the work, as is often necessary when marking small work. For widths above 10 or 11 inches we must have recourse to the gauge shown in Fig. 2043, called the panel gauge. Its sliding piece may be 7 inches long and the stem 2 feet; the rabbeting at *A* forms a steadying base, the part of the

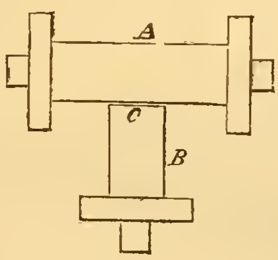
2044.



2045.




2046.

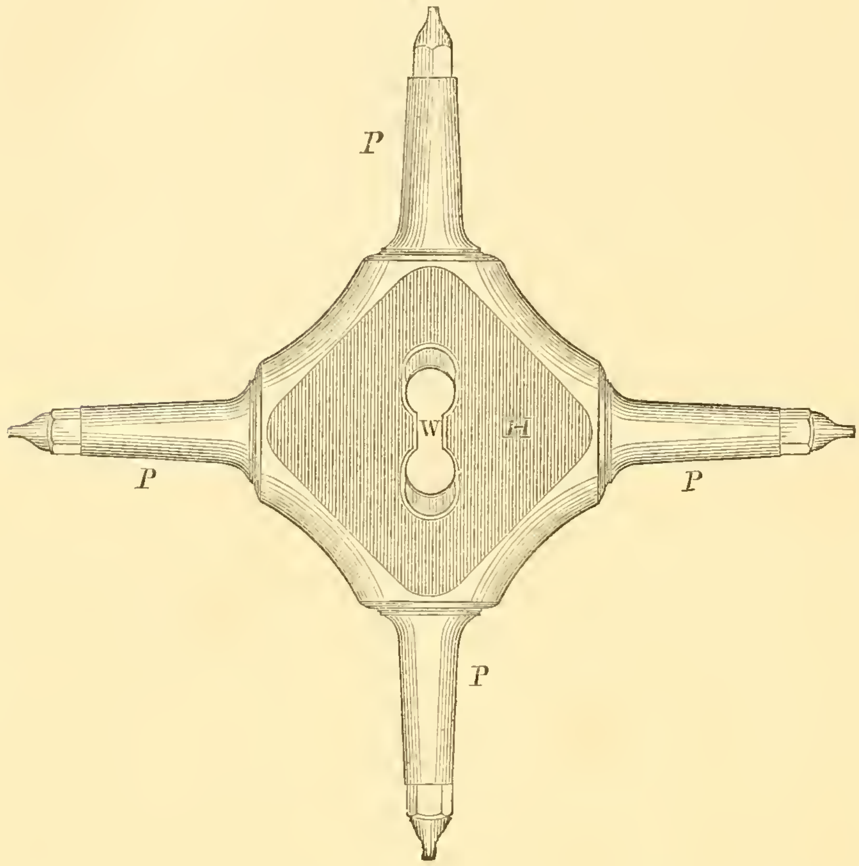



rod about the marking-point being raised to correspond with the distance from the rabbet to the stem nut. Next we have the cutting gauge, shown in Fig. 2044, in which a steel cutter takes the place of the marking-point, being wedged in position. It is employed to cut strips of wood, rubber, etc., of thicknesses up to about a quarter of an inch. The cutter-point should be tempered to a dark straw color.

*The Trammel Gauge* is an exceedingly useful implement, of which but little appears to be generally known. It is shown, together with its method of application, in Fig. 2045. It enables the operator to strike a true circle upon a round or uneven surface. It is composed of the turned bar or rod of metal *A*, of about half an inch diameter, and upon it slides the piece of brass tube *B*, upon which is contrived a support for the sliding arm *C*, as well as a set-screw for fastening the arm *C* in any desired position. At the end of the arm *C* is placed an arrangement for fastening the scriber *D*, so that the scriber may be set at any requisite distance from the rod *A*, by adjusting and

fastening the arm $C$, and revolved about while lifted or lowered upon the rod $A$. If the stand $E$, pierced with holes for screwing down, is provided, it will be a very useful addition.

2047.

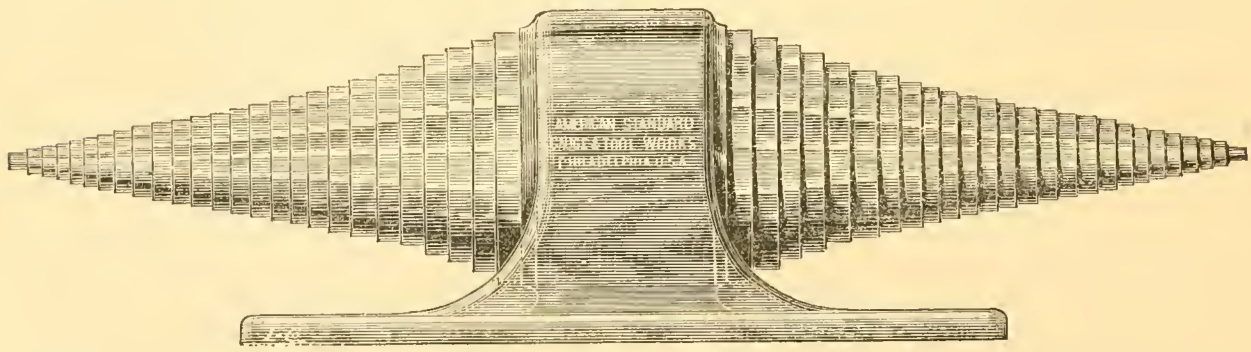



Suppose it is required that the end $C$ of the cylindrical branch-pipe $B$, in Fig. 2046, shall be fitted to the main stem $A$. Take a planed board and gauge a line upon it, and at a point on this line describe a circle upon it of the size of the foot of the instrument. Then make two V-blocks, $G$ $G$, Fig. 2045, to carry the branch, place them with the apex of the V exactly over the gauged line, and place the branch in the Vs. Then set the point of the scriber at a distance from the rod of the trammel equal to the diameter of the branch, which may be readily done if the size of the rod be known. Next mark upon the top of the branch, as it lies in the Vs, the distance it requires to be cut out to form the curve. Draw the branch forward until this mark falls exactly under the scriber; and this adjustment being made, fix temporarily the branch to the piece of board whereon it and the Vs rest. Then move the arm $C$, Fig. 2045, a half circle, and, letting the point of the scriber contact with the branch, draw the necessary line. It will be found, however, that it is requisite to mark the lines while lifting the arm, to prevent the scriber from digging into the wood. Thus one side of the branch will be marked. Then turn it upside down on the Vs, set the joint vertically again, adjust the mark to the scriber-point, and proceed as before to mark the other side of the branch; and the lines so drawn will be of the exact curvature of the body $A$ of the branch-pipe in Fig. 2046.

*Ring Gauges* are used for testing the diameters of projectiles. Two sizes are used. The projectile must pass through the large ring in every direction, and not at all through the small one. Ring gauges $2\frac{1}{2}$ inches wide in aperture are used for determining the size of broken stone in road-making under the Macadam system. A jeweler's ring-gauge is a tapering piece of wood or slip of metal upon which are marked the sizes for finger-rings.

*The Star Gauge* is an ingenious device for obtaining the exact dimensions of the bore of cannon. It is composed of three parts, the staff, the head, and the handle. The staff is a brass tube made

2048.



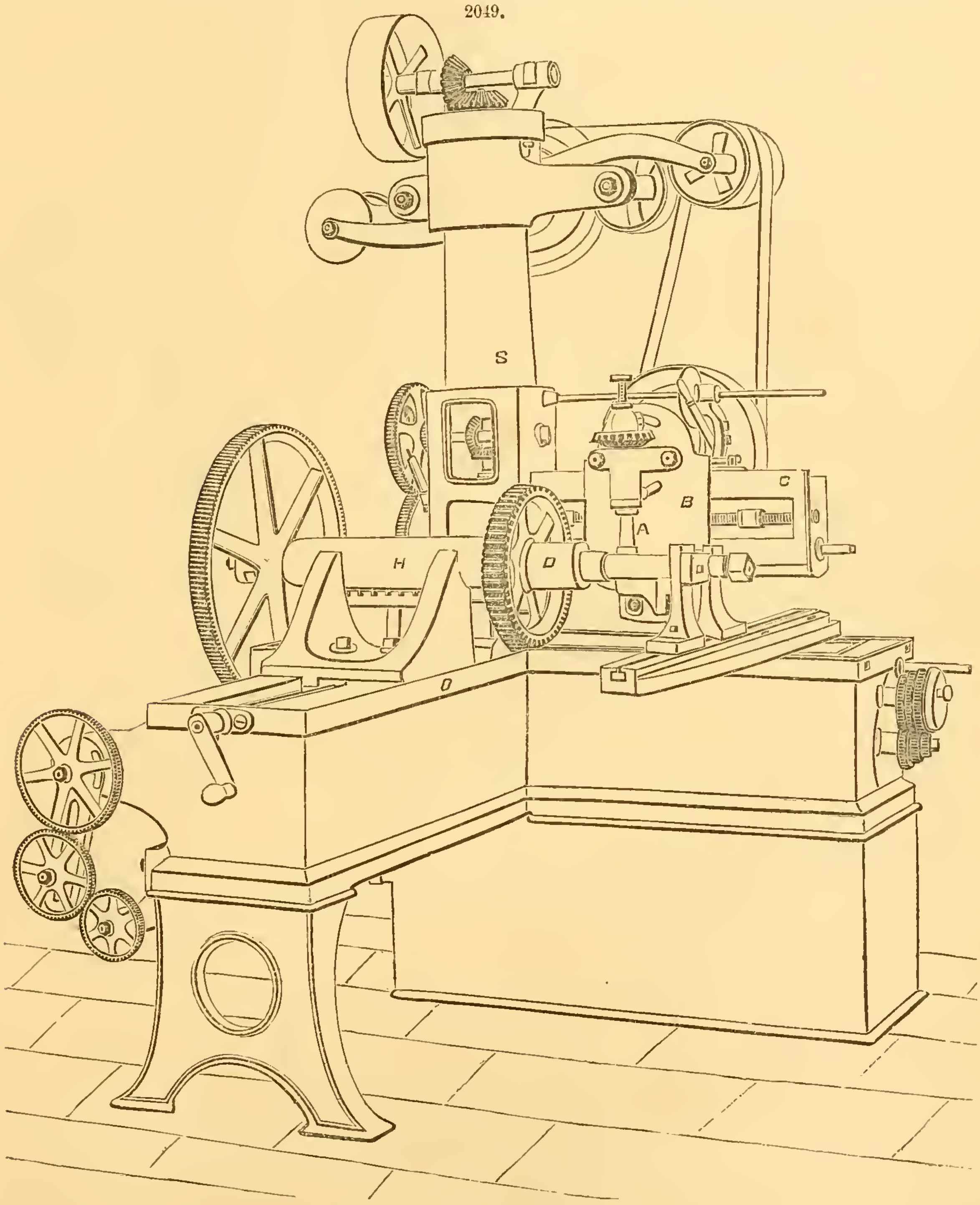
in three pieces, connected together and graduated to inches and quarters, so that the distance of the head from the muzzle of the gun may always be known. The inner end of the staff expands into the head $H$, Fig. 2047, in which are placed four steel sockets at equal distances apart. Two of these are permanently secured and two are movable. A wedge or tapering plate $W$, the sides of which are cylindrical, runs through a slit in the head, and when it is moved forward or backward the sockets are projected or withdrawn. The tapering of the wedge has a certain known proportion to its length, so that if it is moved in either direction a given distance, a proportional movement is imparted to the sockets. There are four steel measuring points $P$ for each caliber of gun. A sliding rod is connected with the wedge and moved by a screw in the handle. The amount of movement of the

measuring points in various places in the bore of the gun is thus registered on an exceedingly fine scale on the handle; and any deviations of the inner surface of the bore from a true cylinder of standard dimension is indicated.

*Caliper-Gauge Testing Apparatus.*—Fig. 2048 represents a device for testing and correcting fixed caliper gauges, and also as a reference in any case to prove dimensions within its range. The disks are separate, ground independently to standard size, and tested by the measuring machine. They are made of steel, and not hardened. The usual set, as shown, is made to embrace 51 sizes, advancing by sixteenths from one-eighth of an inch to 2½ inches, and by eighths to 4 inches. J. R. (in part).

GEAR-CUTTING MACHINES. Machines for cutting the teeth of gear-wheels. Figs. 2049 and 2050 represent Messrs. William Sellers & Co.'s apparatus. The wheels are held upon a stationary

2049.

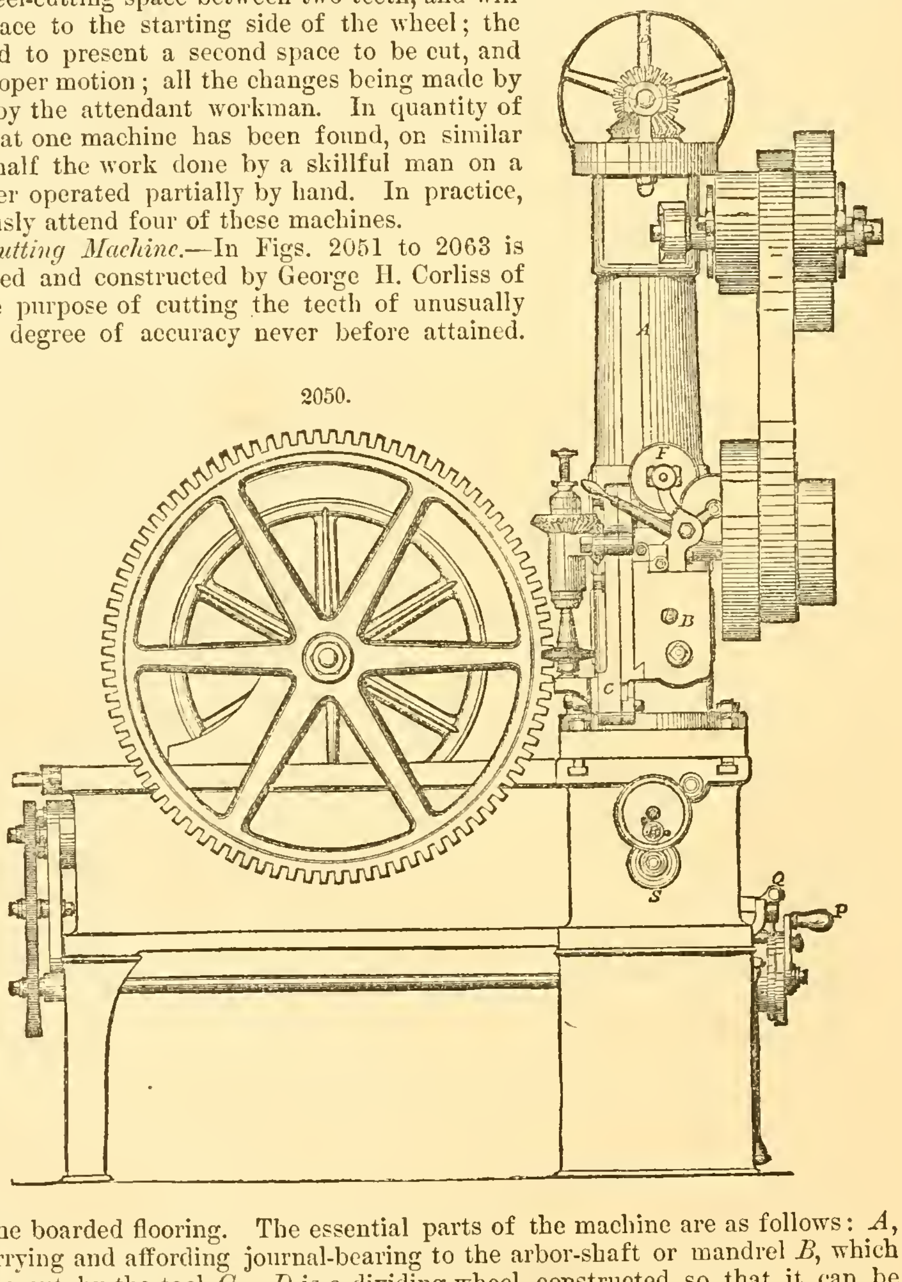



mandrel, and a revolving cutter traverses across the wheel-face, cutting through the latter a groove whose form is determined by that of the cutter. After a cut is taken, the cutter is traversed rapidly back, the wheel is revolved the distance required, and the cutting again proceeds. The essential parts of such a machine are: a mandrel to hold the work, and having in connection with it a mechanical device by means of which this mandrel may be moved through any required fraction of a revolution; mechanical means of revolving and traversing the cutter; and adjustability of the parts of the machine to suit the size and shape of the work. In Figs. 2049 and 2050 is shown a machine automatic in all its motions, and designed for cutting either spur- or bevel-wheels of any size, from 54 inches diameter and 12 inches face downward. *A* is the revolving spindle, carrying the cutter. The

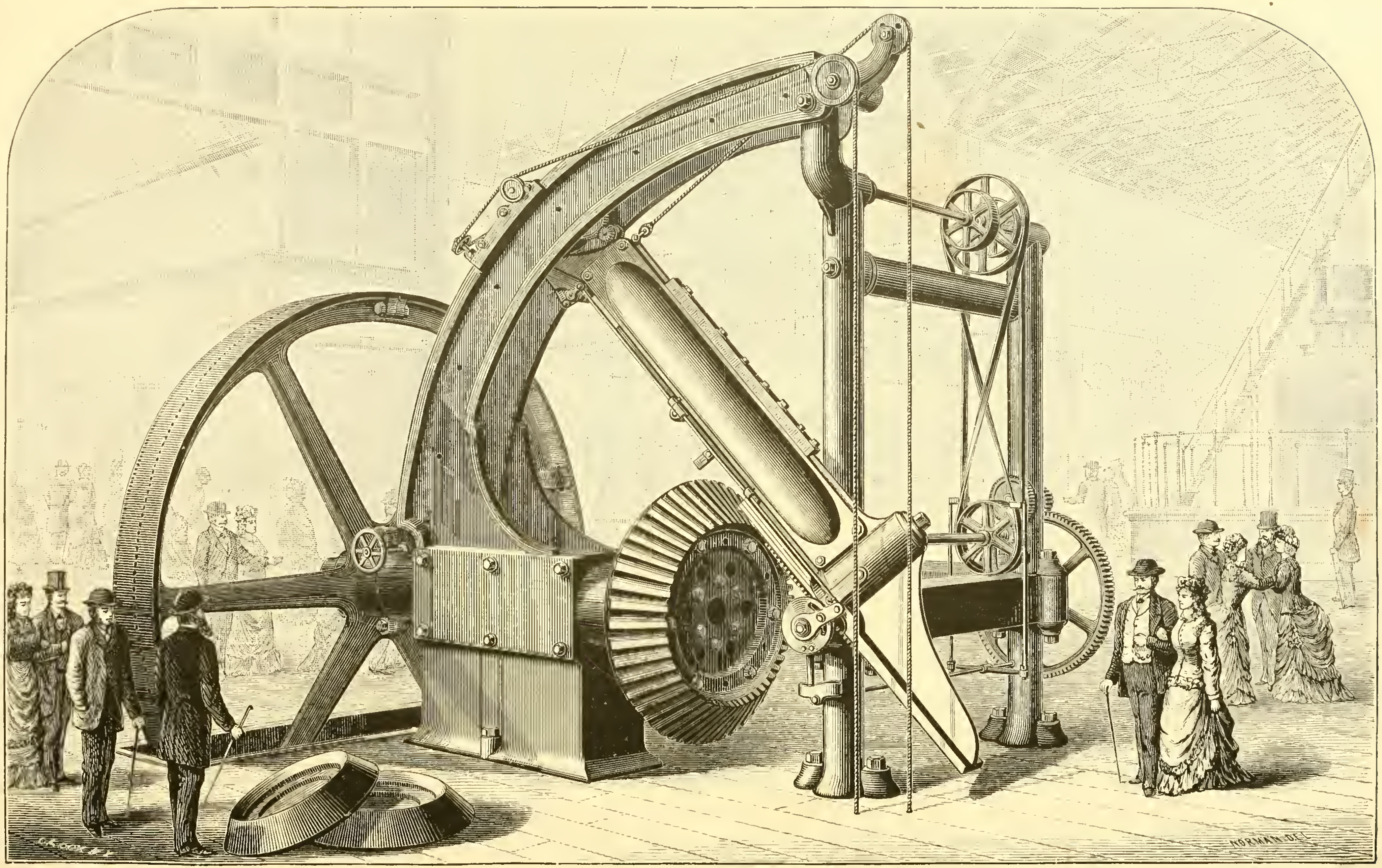
head $B$, carrying $A$, slides or traverses upon $C$. $D$ is the mandrel, upon which is shown a gear-wheel in Fig. 2049. To cut bevel-wheels, the plane of the slide $C$ is set at an angle to the plane of the mandrel $A$. This is done by adjusting the position of the standard, which turns upon the bed on which it rests, and is adjustable to any position; the cone-pulleys, being held to the same casting, swing with it, the whole being firmly locked in the adjusted position of the bolts at the base of the column or standard $S$. The head $H$ is adjustable to suit the diameter of the wheel to be cut by sliding along the part of the frame $O$. The number of divisions, or in other words the number of teeth cut in a wheel, will depend upon the part of a revolution through which the mandrel $D$ is revolved at the end of each return traverse of the cutter; and this is arranged to suit the requirements by means of a tangent-wheel and worm-screw very carefully and accurately constructed, and by the additional use of change gear-wheels, and the turning of the handle $P$ one, two, or three times, as may be called for on the schedule of division. This turning of the handle, however, and all other motions, are done by the machine itself. Thus, a blank wheel being put in place and the proper cutter adjusted to depth of teeth, length of stroke of cutter-head, etc., the cutter will pass across the face of the wheel-cutting space between two teeth, and will then return at a quick pace to the starting side of the wheel; the blank will then be turned to present a second space to be cut, and the cutter will start its proper motion; all the changes being made by the machine itself, not by the attendant workman. In quantity of work done it is stated that one machine has been found, on similar work, to do once and a half the work done by a skillful man on a gear-cutter of equal power operated partially by hand. In practice, one man can advantageously attend four of these machines.

*Corliss's Bevel-Gear Cutting Machine.*—In Figs. 2051 to 2063 is shown a machine designed and constructed by George H. Corliss of Providence, R. I., for the purpose of cutting the teeth of unusually large bevel-gears with a degree of accuracy never before attained.

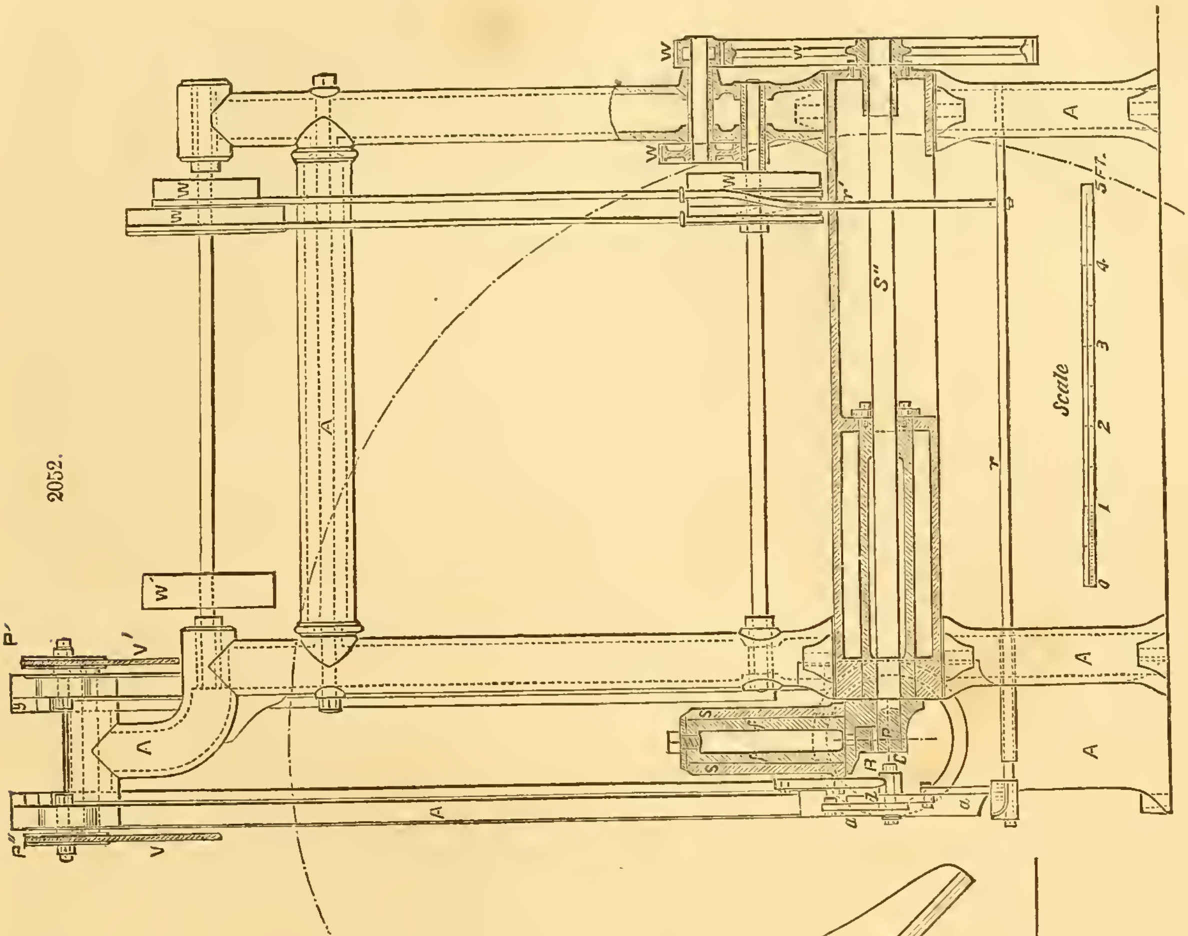
2050.



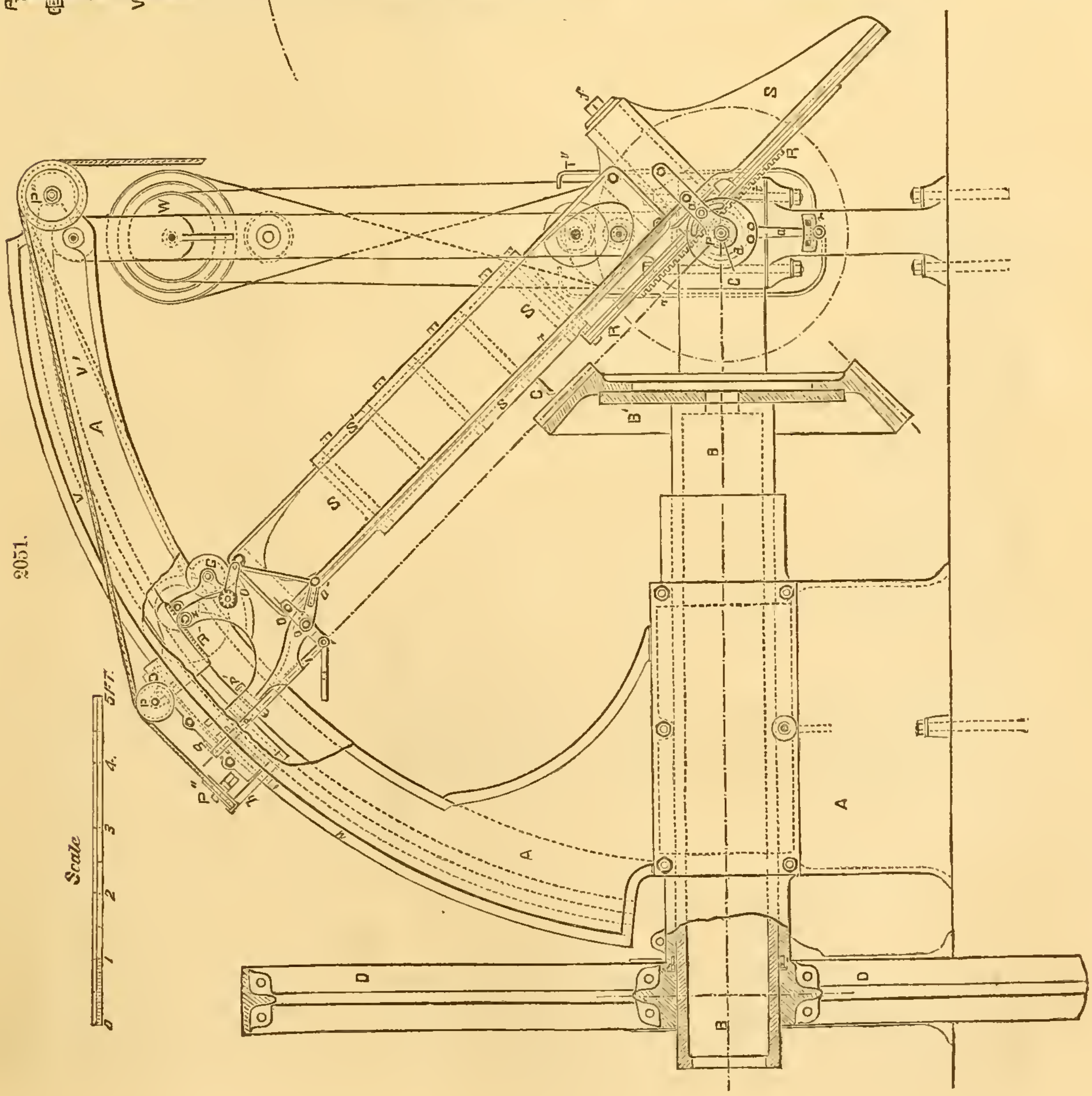

It was designed to cut the teeth of the bevel-wheels employed in connection with the shafting at the Centennial Exhibition in Philadelphia. These wheels were remarkable for the quietness and smoothness of their action. They were 5 feet $8\frac{3}{4}$ inches in diameter, had 54 teeth of 4 inches pitch, and ran at a speed of 2,245 feet per minute, with less vibration or sound than was produced by the leather belts attached to the pulleys at the opposite ends of the short sections of intermediate shafting driven by the bevel-wheels. It is worthy of note that the most delicate operations performed in watch-making were carried on in close proximity to these gears, the lathes and other machines standing directly upon the boarded flooring. The essential parts of the machine are as follows: $A$, Fig. 2051, is a frame carrying and affording journal-bearing to the arbor-shaft or mandrel $B$, which carries the wheel $B'$ to be cut by the tool $C$. $D$ is a dividing-wheel, constructed so that it can be moved with mechanical precision through any required portion of a revolution, and having a device to lock it in any adjusted position. The operation is to cut down one side of a tooth on $B'$, then move the index-wheel through that part of a revolution which is necessary to revolve $B$ to the amount of its pitch, and cut down the same relative side of the next tooth, and so on all round the wheel. The upper part of the frame $A$ forms a quadrant of a circle, and serves to carry the devices which govern the motion of the radial frame $S$ at that end. This radial frame has for the centre of motion of all its movement a point denoted by $C$, Fig. 2053; and $C$ being true with the axial line of $B$, it represents in all cases the centre to which the lines of the sides of the bevel-teeth converge. The upper end of the radial arm $S$ is adjustable vertically, and is permitted a slight lateral motion, both movements operating from the point $C$. The body of the radial frame $S$ serves as a slide-guide whereon traverses the carriage to which is attached the cutting tool $C$. The perimeter of the quadrant frame $A$ is provided with a slide whereon traverses a carriage adjustable to any required



THE CORLISS GEAR-CUTTING MACHINE.




2052.

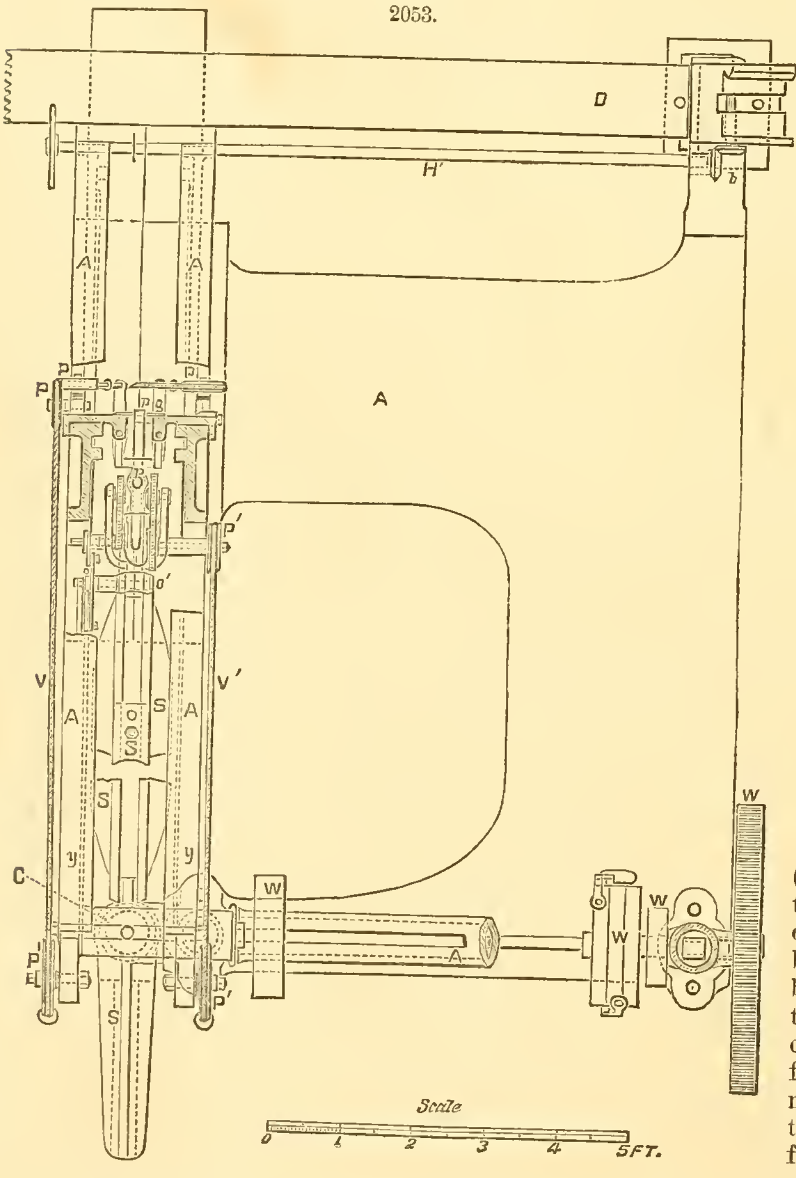



2051.

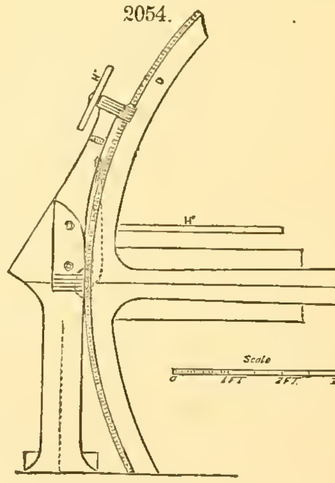
position on the quadrant. This carriage carries and maintains stationary in its adjusted position a templet of the shape of tooth requiring to be cut. To the end of the radial frame $S$ is attached a pin; hence, by lowering $S$ while the pin is in contact with the curves of the templet-tooth, the motion of $S$ at that end will exactly conform to the shape of the templet-tooth, while its motion will diminish in amount, though remaining constant in direction, as the point $C$ is approached. From this it will be perceived that one former or templet-tooth may be employed to cut wheels of varying diameters, giving to the teeth of each its proper curves and depth of tooth, all that is necessary to insure exactitude being to set the various bevel-wheels at their proper distances from the point $C$. The machine is provided with pivoted rack-teeth, to give to the radial frame $S$ the lateral motion necessary to allow its outer end to conform to the shape or curves of the templet-tooth. It has a quick return motion for the cutting tool on its back traverse—a device which relieves the cutting tool from contact with the surface of the tooth on the return stroke, while at the same time it relieves the pin from contact with the templet-tooth during the elevation of the outer end of $S$; and it has other ingenious devices, which will be presently explained in detail. The machine is constructed with every refinement of fit and accuracy of measured dimensions, while at the same time its design eliminates to a great extent those minute errors which are inseparable from the finest of mechanical manipulations. Thus the dividing-wheel $D$ is 15 feet in diameter, so that if the bevel-gear wheel operated upon is 5 feet in diameter, whatever error might exist in the divisions of the index-holes of $D$ will be reduced to one-third as much only in the bevel-wheel. The former or templet-tooth is 9 inches long upon its operative surface, whereas the depth of tooth on a 6-foot bevel-gear wheel would be about $2\frac{1}{2}$ inches only, reducing any possible error in the curves of the templet to a corresponding proportion in the tooth cut.

The machine is operated as follows: The radial frame $S$ is raised (at its outer end) out of the way, and the mandrel $B$ is moved back. The wheel to be operated upon is bolted to the end of the mandrel $B$, its hub fitting into a true bore provided in the mandrel. The bevel-wheel is so chucked upon the mandrel that, when the index-pin is in place in one of the index-holes of the wheel $D$, the tool will be allowed its proper amount of cut upon the side of the tooth standing beneath it. The bevel face of the wheel to be operated upon having been turned to the proper angle, the operator lowers the radial frame or arm $S$, and so adjusts it and the distance of the mandrel $B$

2053.




2054.

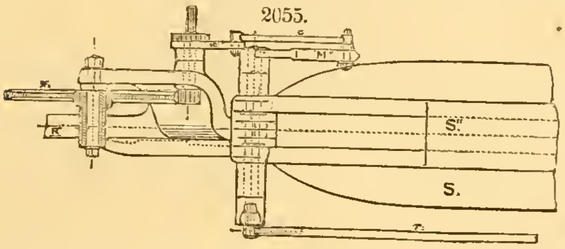



(in its relation to the point $C$) that the guide or slide surface of $S$ stands parallel with the bevel surface of the wheel, and both the depth and the shape of the tooth will be cut automatically by the machine to correct form. This adjustment is easily made by traversing the cutting tool over the turned bevel surface of the bevel-wheel. This adjustment completed, the carriage holding the templet-tooth is rigidly fastened to the quadrant, and the guide-pin on the end of $S$ is brought into contact with the templet-tooth at its pitch-line. The tool is then adjusted so that its cutting point stands even with the pitch-line of the wheel to be cut. The guide-pin upon and with $S$ is then brought to the top of the templet-tooth, and the machine is started. The pinion $P$, operated by belt power, revolves, moving the rack $R$, which in turn operates the sliding carriage to

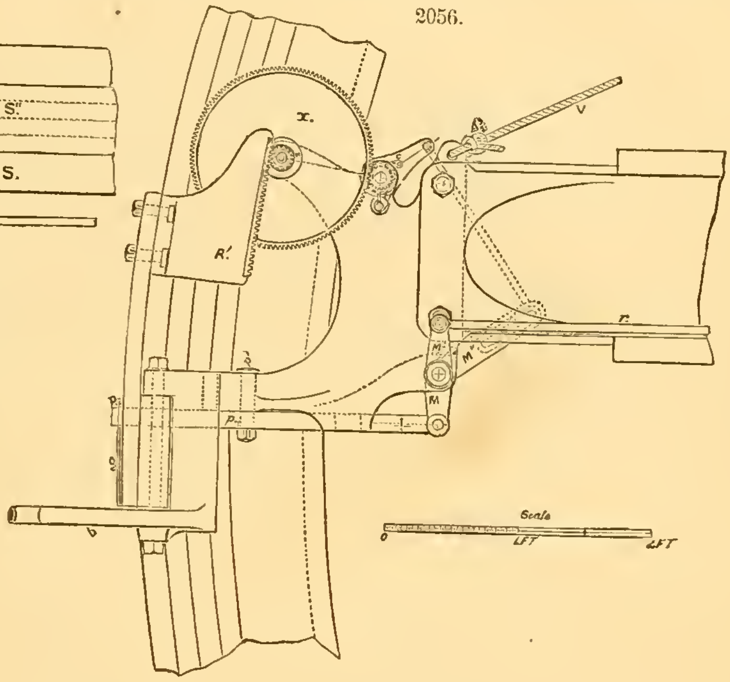
which the cutting tool is attached. When the carriage, or what is the same thing, when the cutting tool has traversed the required distance, a rod attached to it operates a belt-shipper, the direction of rotation of $P$ is reversed, and the carriage and tool travel back, the feed of the tool taking place at the end of the back traverse and proceeding from the point or top toward the flank or bottom of the tooth. The tool cuts while traversing toward the infinite point $C$, so that the resistance offered by the cut shall operate to balance the weight of the carriage, the cutting tool and holder, and the rack.

Such is a general description of this machine, and we may now describe its construction in detail, reference being had to the drawings, of which Fig. 2051 is a sectional side elevation; Fig. 2052, a sectional front elevation; and Fig. 2053, a plan view of the machine as a whole; while Fig. 2054 is a back view of the device for rotating the dividing or index wheel $D$. Fig. 2055 is a top

2055.



2056.

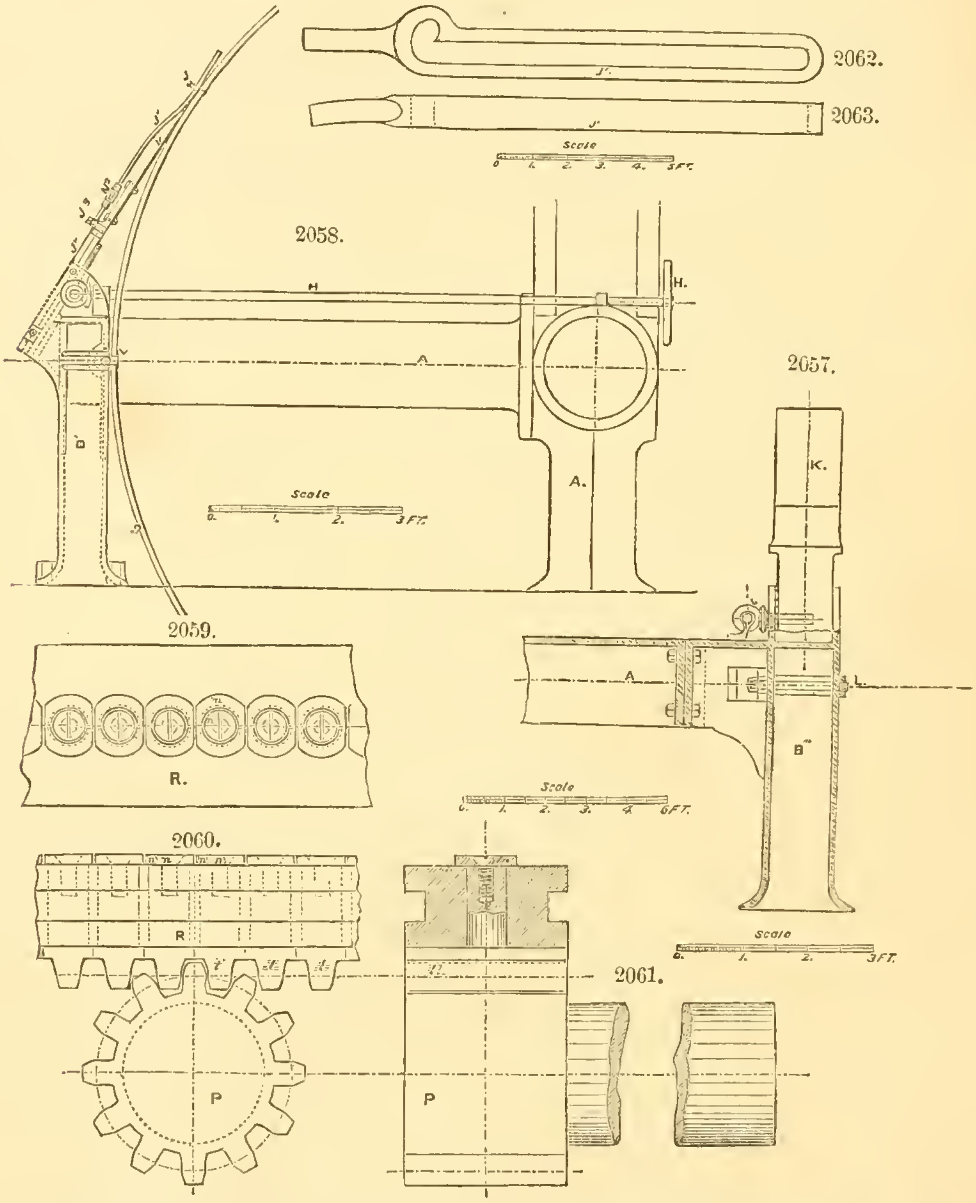


view, part in section, and Fig. 2056 is a side elevation, of the feeding and guiding device attached to the upper end of $S$. Fig. 2057 is an end and Fig. 2058 a back view of the device for locking the dividing or index wheel in position after adjustment. Fig. 2059 is a top and Fig. 2060 a side view of the rack $R$ and pinion $P$; and Fig. 2061 is a sectional view of the same. Figs. 2062 and 2063 are two views of the slotted link for insuring an exact recurrence of the divisions. In all these drawings similar letters of reference indicate similar parts. The method of rotating the index-wheel $D$ is shown in Fig. 2054. The rim of the wheel is provided with cut teeth in gear with the pinion operated by the hand-wheel $H'$. The circumference of $D$ is provided with 216 equidistant index-holes, and to remove that wheel through any definite portion of its revolution it is simply necessary to withdraw the pin $J$, Fig. 2058, from an index-hole, and operate the handle $H''$ until the wheel $D$ has rotated the required distance, when $J$ will again enter an index-hole. Thus, if the gear to be cut is to contain 216 teeth, the wheel $D$ will be required to move so that the pin $J$ falls into the next index-hole at each adjustment; or if the wheel to be cut is to contain 108 teeth, then at each adjustment $J$ will fall into every other index-hole. After the wheel $D$ is adjusted and the pin $J$ is in position, $J$ is relieved of the strain due to holding the wheel $D$ against the pressure of the cut, and also from any lateral vibration by the adjustable jib $L$, Figs. 2057 and 2058, which is caused to bear upon the rim of $D$, clamping it truly in its adjusted position. To avoid the necessity of counting the number of index-holes to be passed by the pin $J$ at each adjustment of $D$, and to eliminate the possibility of error that might occur if the operator was required to count those holes at each adjustment of $D$, the ingenious arrangement shown in Figs. 2058, 2062, and 2063 is provided.

The devices for feeding $S$ to the cut are as follows: Figs. 2055 and 2056 are views of the parts at the outer end of $S$. $p$ is a steel pin pivoted by the stud or bolt $p'$ round upon its outer end, which contacts on the down feed of $S$ with the former or templet-tooth $g$, and of wedge form at its inner end. The guide $g'$ holding the templet-tooth is secured in its adjusted position to the perimeter of $A$. The templet-tooth $g$ being curved to the circle of the perimeter of $A$, the variation in the form of its curve, due to its curvature, is allowed for in its construction; for it is evident that the amount of lateral motion imparted by a given degree of curve in the templet-tooth to the end of $S$ will be less at the point of attachment of the tool $c'$ in proportion as the point of contact of $p$ is radially removed from the infinite point $C$. The carriage fixed to $A$ $A$, and holding the templet-tooth $g$, is provided with the rack $R'$. A casting bolted to the end of $S$ constitutes a frame carrying the stud $p'$, the lever $M'$, the pinion shown at $c'$, and the gear-wheel $x$. The rod $r$ is moved laterally at each end of the motion of the carriage $S'$, and, through the medium of $M$, $M'$, and $M''$, operates the arm carrying the ratchet-tooth $c$; thus, as the arm $r$ moves in the direction denoted by the arrow (Fig. 2056), the catch $c'$ partly rotates the pinion at $c'$, which moves the gear $x$ as denoted by the arrow and the pinion $x'$, causing $S$ to descend to an amount proportionate to the movement of $M''$, the latter being regulated by the position of the end of $M''$ in the slot provided in $M'$. To relieve the gears and rack-teeth of the weight of $S$ and its appurtenances, the cord $x'$ is provided; it passes over a pulley $p''$ (Fig. 2051), and supports a weight beneath the floor.

The method of giving to $S$ the slight lateral movement necessary to relieve the cutting tool from contact with the work, and the pin $p$ from contact with the templet-tooth, on their respective back traverses, is as follows: Upon each side of the pin $p$ is a lever $h$, and to one or the other of these levers (according to which side of the wheel-tooth is being operated upon) is attached the cord

$x$ passing over the pulleys $p''$ $p''$, of which there is a set on each side of the machine, and carrying a weight beneath the floor. It is obvious that the templet-tooth $g$ must stand with its curve in the same plane as the curve of the tooth being cut; hence, after all the teeth of the wheel have been cut on one side, the templet-tooth is turned over and the other sides are cut. Now the cord $x$ is attached to the lever $H$; this is necessary to keep the pin $p$ in contact with the curve of the templet-tooth, on whatever side that curve may stand, unless relieved by a separate device which operates on the return traverse of the cutting tool, and which is arranged as follows: The body of $p$ at $I$ is wedge-shaped, being tapered on its vertical sides from $I$ toward the pivot at $p'$, and it operates between two similarly inclined or wedge-shaped surfaces stationary at $I'$, contacting during a part of its movement with the fixed wedge on the same side of it as the cord to it is fastened. When the tool begins its up and return traverse, the rod $r$ moves in the direction of the arrow, and through



2057. 2058. 2059. 2060. 2061. 2062. 2063.

the medium of $M'$ and $M$ advances $p$; its taper part at $I$ contacts with the fixed wedge, and causes $p$ to swing slightly on the pivot-stud $p'$, and remove its round end from contact with $g$; then, as the motion of $r$ is reversed, the side face of $p'$ at $I$ is removed from contact with the fixed wedge, and the rope at $h$ is permitted to again hold the pin $p$ against $g$. To permit of the lateral motion of $S$, the teeth of the rack $R$ are pivoted at their centres by steel pins, as in Figs. 2059, 2060, and 2061.

Previous to the introduction of this class of gear-cutter by Mr. Corliss, it was not attempted to give to bevel gear-wheel teeth the true form of curve, the practice being to operate upon one side of the space at a time, using two or three cutters, giving a correct form at one or two points only, and trusting to the wear of the surfaces to give better contact. The bevel-wheels referred to as having been cut by this machine show upon examination, after their six months of duty, that the bearing surface on the driving and driven sides of the teeth is smooth and polished, the wear having been sufficient merely to efface the tool-marks made in cutting the teeth, while on the following or follower side of the teeth the tool-marks remain, showing no abrasion or wear. J. R.

END OF VOLUME I.